March/April 2000

Zoogoer

Volume 29 / Number 2

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MARCH/APRIL 2000 VOLUME 29, NUMBER 2

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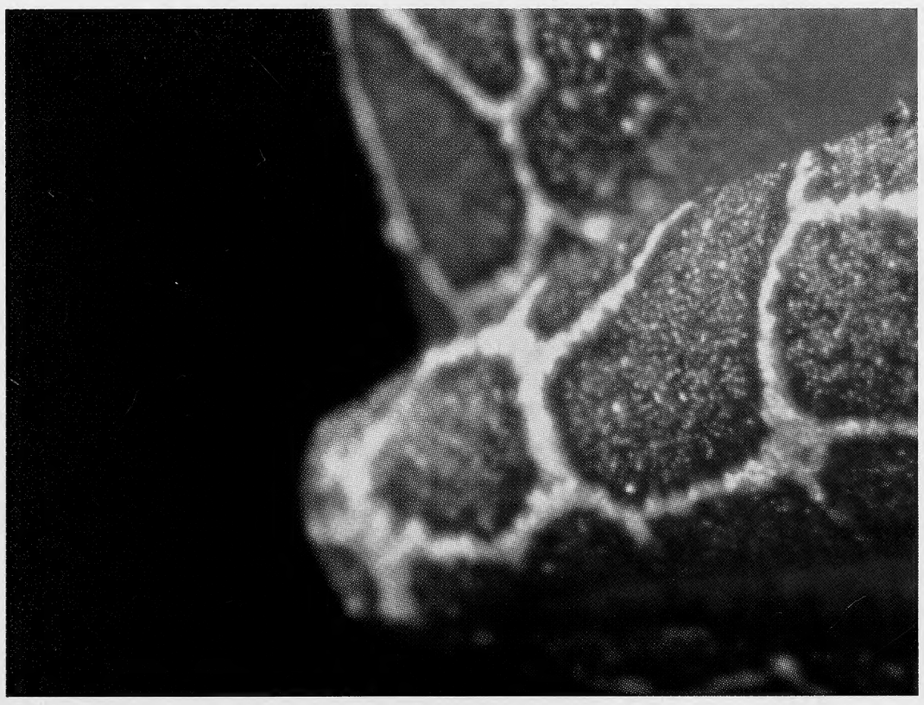

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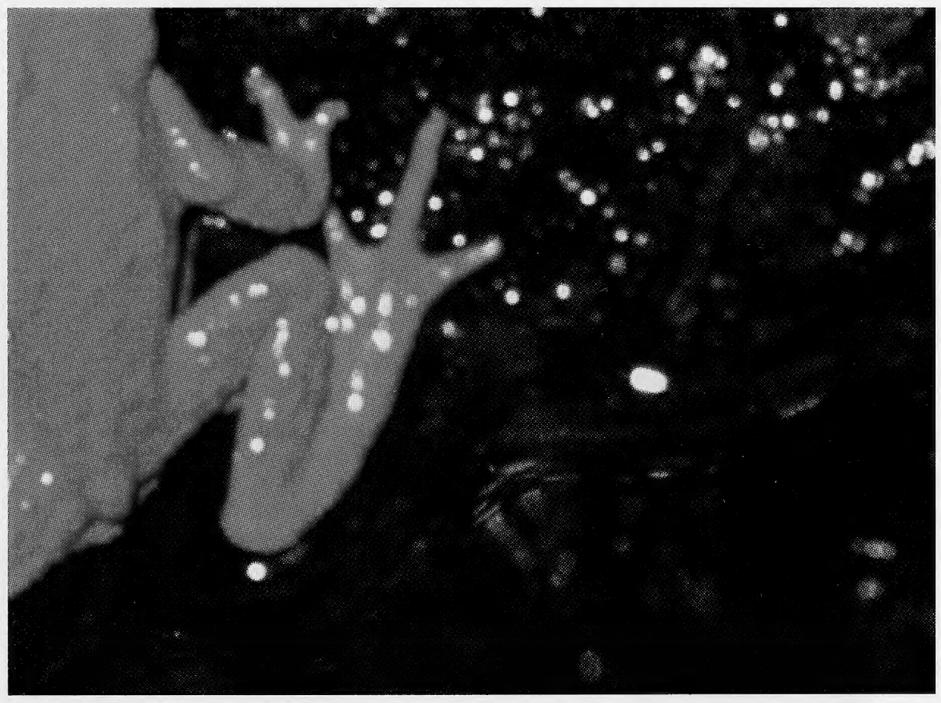

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"A word or two BEFORE I GO..."

JESSIE COHEN/NZP

"A word or two before I go..."

Thus spake Othello; the incomparable Raymond Chandler wrote *A Long Goodbye*, and poet and essayist Robert Graves called his memoir *Goodbye to All That.* I'm saying goodbye on April 30, when I retire after 16 years, *mas o menos*, as Director of the National Zoo (I came here in May 1984). Here we are in a new century, and what is either the eve of a new millennium or actually the third one of the Modern Era, depending on how one calculates the start. For me it is a time for nostalgia, retrospective analysis, and sadness. The sadness comes from saying goodbye to all this: to friends, to a daily encounter with challenges and delights, and to a rewarding relationship with all facets of FONZ.

I will not be saying goodbye to the Smithsonian Institution until somewhat later because I'm going to be engaged in biological research in the tropics. This sabbatical adventure is based on my arrogant assumption that I've still got a brain. I know I've still got the necessary curiosity and a recent visit to the rainforests of Puerto Rico reassured me about my visual acuity. I discovered, to my satisfaction, that I can still see the small creatures, including tiny male spiders, that have always engaged me.

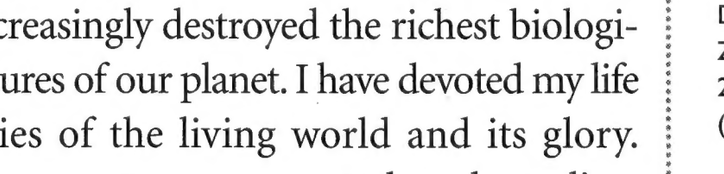
The Zoo Years have been a source of deep joy. The idea that education for conservation was the primary function of zoos was first seen as heresy in the profession but is now prominent in everyone's agenda. In these 16 years we have completed a series of outstanding buildings starting

with the new Veterinary Hospital at Rock Creek. This building freed up space for the reconstruction and modernization of the Zoological Research Building, which is now one of the best equipped in the world. Public exhibits have included the Invertebrate Exhibit, Amazonia, Think Tank, the Gibbon Exhibit, Grasslands, Cheetah Conservation Station, the new Wetland area, the rebuilding of Olmsted Walk, and so on. Our ties with the rest of the Smithsonian have been widely emphasized and we have a marvelously dedicated and skillful staff in all departments. Wow! How difficult to say goodbye to that.

When one looks back over the years there are momentous moments that may constitute nodal points in life. For me, the start of Biophilia may well have been very early in the 1930s when my mother took me to the local park. I was at the early walking stage, but mainly crawling like a four-legged caterpillar. There in the park's grass-blade jungle, down at bug level, I encountered a red furry bee that burns in my memory to this day. It buzzed, and crawled like me, before entering a miniature mole-hole in the ground. Clothed in lustrous golden-red hair it was as attractive as the plush toy Teddy Bear that I clutched in my cot. Much later in life, solitary bees became a subject of scientific interest. The return of the native.

All in all, animals have enriched my life beyond all rationality. I have been supremely lucky. Creatures ad infinitum marked life in biologically depauperate Britain before I became a professional animal watcher. I was a fervent naturalist until eventually stars crossed and I became a student at Oxford. There I was lucky to join the Animal Behaviour Group headed by this century's premier animal watcher: Niko Tinbergen. His popular book, *Curious Naturalists*, is flaming with a passionate addiction to probing the private lives of a plethora of species. From Oxford sheer luck took me to Panama to work with tropical organisms, and incidentally to the start of a Smithsonian career. Sometime in August 1964, I reached Barro Colorado Island, home of the Smithsonian Tropical Research Institute. There I was to be hired and inspired by then-Director Martin Moynihan, the unmatchable diviner of animal secrets. In Panama and Papua New Guinea my domestic menagerie extended beyond my wildest dreams to include otters, raccoons, kinkajous, jaguarundis, ocelots, wallabies, bandicoots, sugar gliders, and other creatures beyond mention. Nearly 20 years in tropical countries around the world (I have counted more than 33) ended when I became Director here in 1984.

All this reminiscing is a prelude to the most important thing I can say before I go. I have seen nearly three fourths of the last century. It was marked by the megadeaths of humans in wars, civil convulsions, and by awful neglect. It was also a period of triumphant science; perhaps its most stunning discovery being the elucidation of the nature of genetic code. However, in that century we did—and are now continuing to do—something ultimately more irresponsible than anything we humans have ever done. We have increasingly destroyed the richest biological treasures of our planet. I have devoted my life to studies of the living world and its glory. Nothing now moves me more than the realization that we are facing a crisis in biodiversity without parallel in post-glacial history. The rate of habitat destruction has not decreased in the last few years, rather it has increased. Now is the time to renew our energies and work to save the wonders that we have inherited. It is almost too late. I hope the National Zoo will continue its dedication to this noblest of causes. Saving species is not enough, we must save the ever more threatened ecosystems. Otherwise our descendants will inherit a concrete jungle. We will impose the tyranny of our inaction on their future.



Michael H. Robinson
Director
Smithsonian National Zoological Park

Friends of the National ZOO is a nonprofit organization of individuals, families, and organizations who are interested in helping to maintain the status of the Smithsonian National Zoological Park as one of the world's great zoos, to foster its use for education, research, and recreation, to increase and improve its facilities and collections, and to advance the welfare of its animals.

ZooGoer [ISSN 0163-416X] is published bimonthly by Friends of the National Zoo (offices located at the Smithsonian National Zoological Park, 3001 Connecticut Ave., N.W., Washington, DC 20008-2537) to promote its aims and programs, and to provide information about FONZ activities to its members, volunteers, and others interested in the purposes of FONZ. Periodicals postage paid at Washington, D.C.

The Smithsonian National Zoological Park is located at 3001 Connecticut Ave., N.W., Washington, DC 20008-2537. Weather permitting, the Zoo is open every day except December 25. Hours: From May 1 to September 15, grounds are open from 6 a.m. to 8 p.m.; buildings, 10 a.m. to 6 p.m. From September 16 to April 30, grounds are open from 6 a.m. to 6 p.m.; buildings, 10 a.m. to 4:30 p.m. **Director:** Michael H. Robinson.

Membership in FONZ offers many benefits: publications, discounts on shopping, programs, and events, free parking, and invitations to special programs and activities to make zoogoing more enjoyable and educational. To join, write FONZ Membership, National Zoological Park, Washington, DC 20008, or call 202.673.4961.

Membership categories and annual tax-deductible dues are:

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Editor: Susan Lumpkin
Associate Editor: Alex Hawes
Editorial Assistant: Sue Zwicker
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Consulting Editor: Robert Hoage
Copy Editor: Jean B. McConville
Design: Lloyd Greenberg Design
Advertising Sales: Joyce Rains; 301.530.0583

Visit FONZ's website at: www.fonz.org

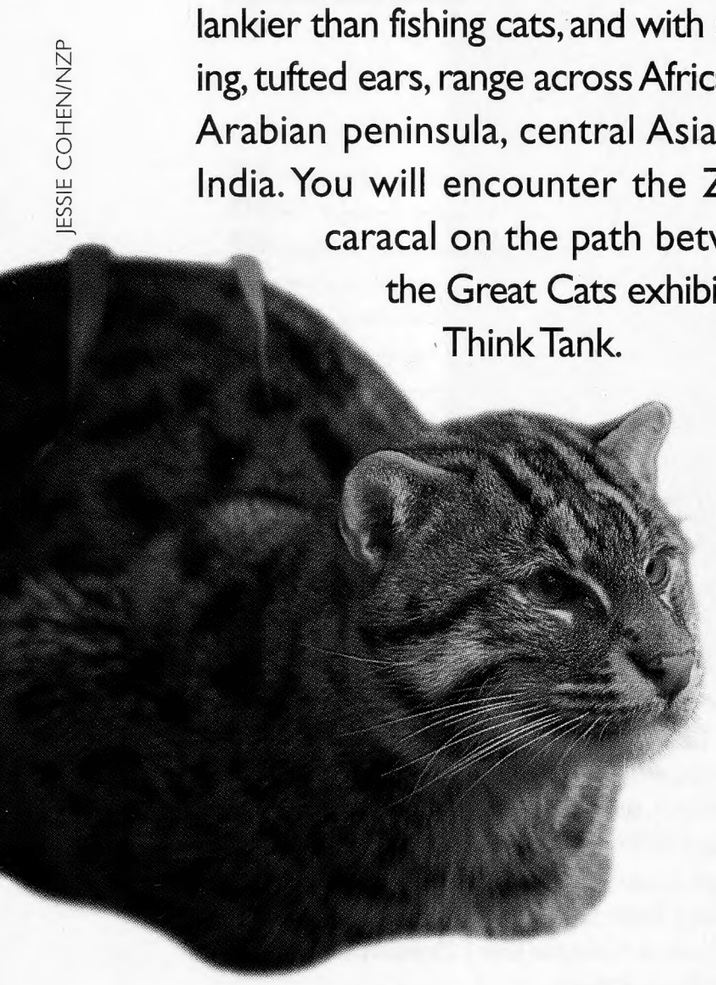
Cover photo: Gray tree frog (*Hyla* sp.) silhouetted on leaf. Photo by John Netherton.

Recycled paper

NOTES & NEWS

ANIMAL NEWS

Attention, cat lovers! Newly arrived at the National Zoo are a pair of male fishing cats (*Prionailurus viverrinus*) and a female caracal (*Caracal caracal*). The fishing cats—elaborately spotted, 15 to 30 pound felines that inhabit swamps and marshy thickets from south and Southeast Asia to Indonesia—can be found at the Zoo in the Forest Carnivores area. Caracals, larger and lankier than fishing cats, and with striking, tufted ears, range across Africa, the Arabian peninsula, central Asia, and India. You will encounter the Zoo's caracal on the path between the Great Cats exhibit and Think Tank.

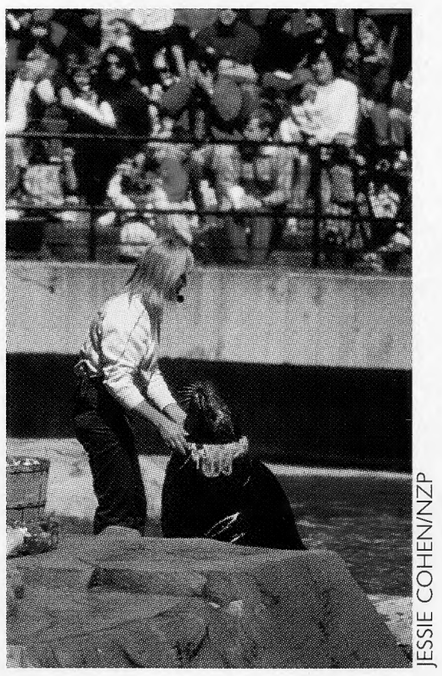


JESSIE COHEN/NZP

FISHING CAT (*PRIONAILURUS VIVERRINUS*).

VERNAL EVENTS

Spring is always a busy time at the Zoo. Friends of the National Zoo kicks off its busy spring schedule with the 17th annual **Seal Days: A Celebration of North American Wildlife**, on Saturday and Sunday, March 18 and 19, from 11 a.m. to 4 p.m. This free event, which coincides with the International Day of the Seal, highlights the Smithsonian National Zoo's grey seals and California sea lions, as well as red wolves, hawks, and other animal residents of the Zoo's Beaver Valley. Hourly animal feedings and training demonstrations, interactive educational displays, talks with animal keepers, and children's crafts and games will take place along the Valley Trail.

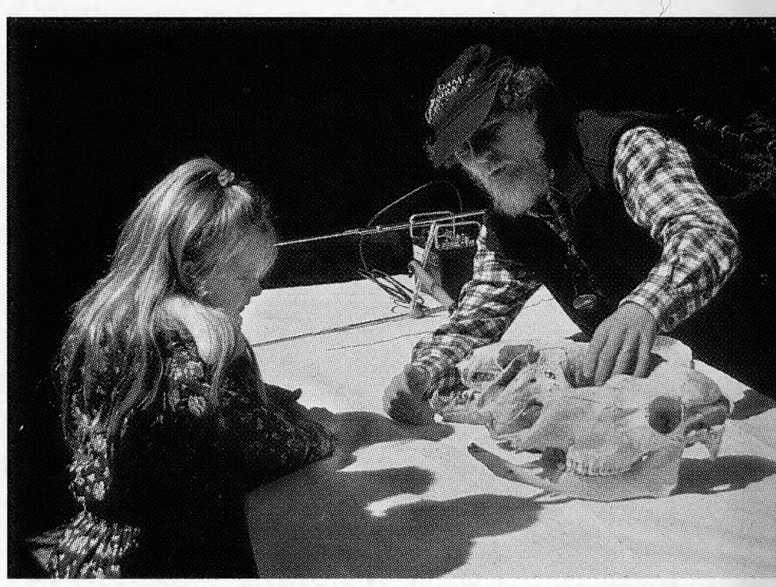


JESSIE COHEN/NZP

The spring fling continues with the next installment of our Young Professional Events, **Salsa with the Salamanders**, on April 13 from 6:00 to 9:00 p.m. Nightlife and wildlife meet as FONZ offers a great opportunity to meet new people, enjoy an animal demonstration, and learn a few new dance steps. Admission is $8 pre-registered, $10 at the door. Call 202.673.4962, or visit www.fonz.org/calendar.htm to register, or for more information.

Family fun continues with the **African-American Family Celebration** on April 24, from 11 a.m. to 4 p.m. This free festival, an Easter Monday tradition in the District, will include an Easter egg hunt, gospel music, African drum performances, and storytelling.

"Find out Why?," part of National Science & Technology Week, follows the next weekend, on April 29 from 10 a.m. to 4 p.m., and April 30 from 11 a.m. to 4 p.m. Sponsored by the National Science Foundation—an organization turning 50 this year—this free event challenges children ages four and up to discover on their own why cheetahs run so fast, why bees are fuzzy, and why flamingos have bent beaks, among other zoological puzzles. Kids can also tackle crafts and watch special animal demonstrations.

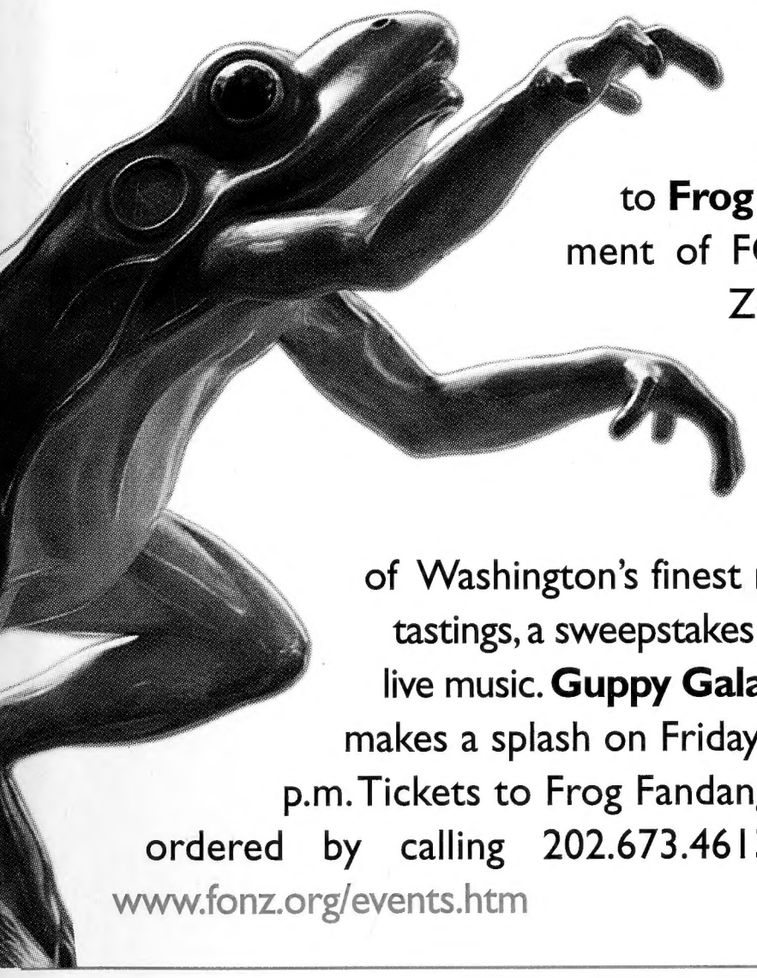


JESSIE COHEN/NZP

This time of year brings the return of our Neotropical avian migrants. The Zoo celebrates this natural phenomenon with the **International Migratory Bird Day Festival** on Saturday, May 6, from 10 a.m. to 2 p.m., and Sunday, May 7, from 11 a.m. to 3 p.m. The free event will feature animal demonstrations, live music, Latin American and Caribbean food, a slide lecture by author and bird enthusiast Scott Weidensaul, and book signings by Lynne Cherry, author of *Flute's Journey* and *The Great Kapok Tree*. Volunteers for the festival are needed; please contact Mary Deinlein at 202.673.4908 if interested. Visitors are encouraged to take public transportation to all events at the Zoo.

ZOOGOER IN ALTERNATE FORMAT

This issue of *ZooGoer* Magazine and all subsequent issues of *ZooGoer* and *Wildlife Adventures* will be available on audio tape. Please call 202.673.4711 or 202.673.7800 (TTY) for more information. The magazine is also available online at www.fonz.org



ZOOFARI 2000

This Leap Year, jump at the chance to buy advance tickets at a discount to **Frog Fandango**, the Y2K installment of FONZ's annual gala event, ZooFari. Frog Fandango will take place on May 18, from 6:30 to 11:00 p.m. The event will feature food and drink from more than 100 of Washington's finest restaurants, as well as wine tastings, a sweepstakes and silent auction, and great live music. **Guppy Gala**, our ZooFari event for kids, makes a splash on Friday, May 12, from 6:00 to 8:30 p.m. Tickets to Frog Fandango and Guppy Gala can be ordered by calling 202.673.4613, or by logging onto www.fonz.org/events.htm

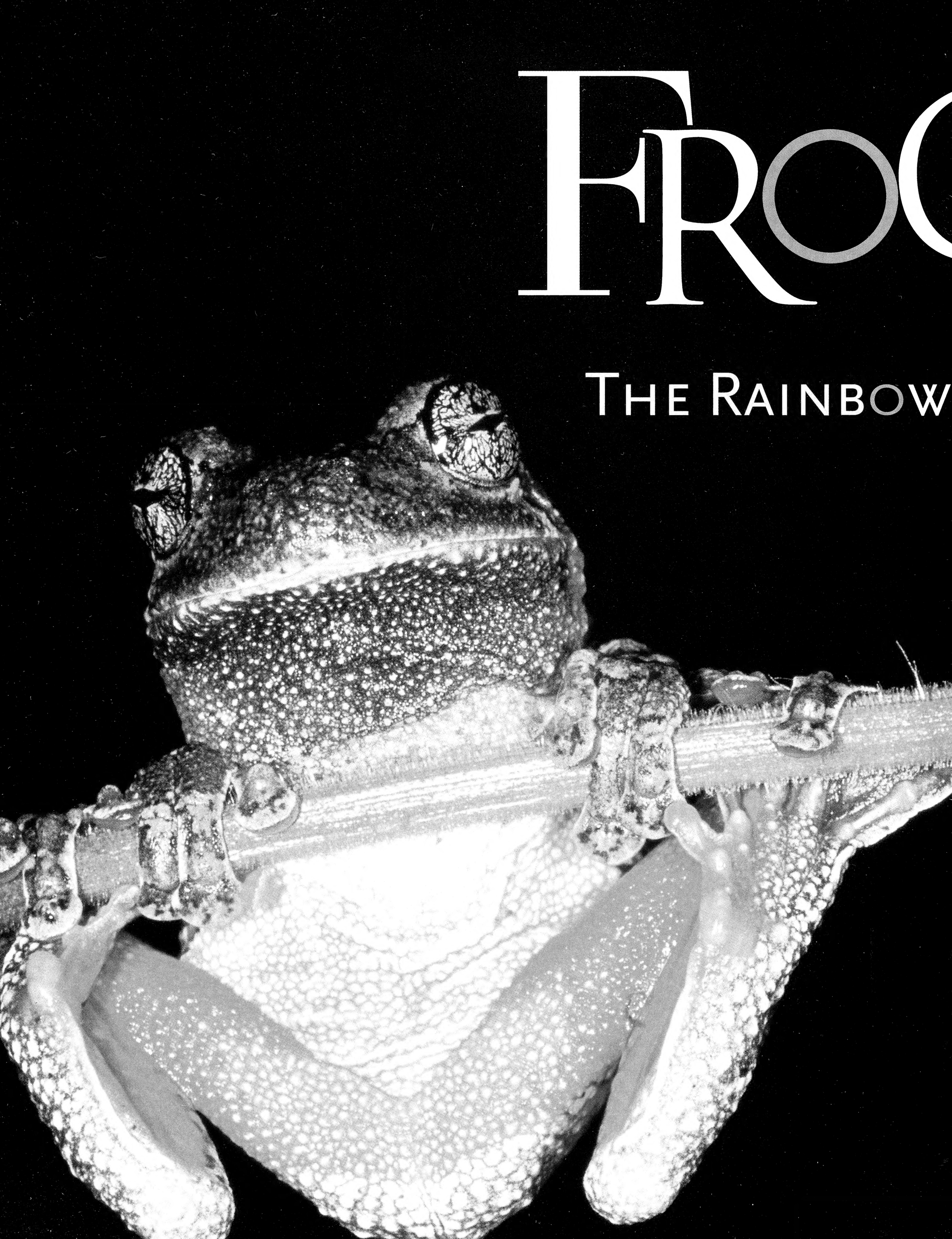
PHOTO CONTEST WINNER

FONZ recently announced the winners of its 23rd annual photo contest. In the general wildlife competition, Gerald W. Ocker won first place for his photo [below] of a pair of Inca terns (*Larosterna inca*) at the National Zoo, while Pattie Austin, Tony Mead, Howard Penn, and Chris Scroggins won honorable mentions for their portraits of Zoo animals. Bart Bridwell won top prize in the butterfly category, and Howard Penn won another honorable mention for his butterfly close-up. To celebrate Earth Day, all winning photos will be exhibited in the Washington Monarch Hotel from April 17 to April 21, and can be seen online at www.fonz.org/events/photowinners.htm

GERALD W. OCKER

INCA TERNS (*LAROSTERNA INCA*).

FROM THE RAINBOW



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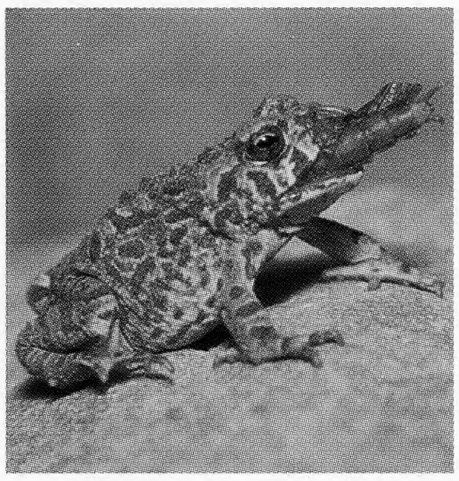
Connection

BY A. STANLEY RAND

Gray tree frogs (*Hyla* sp.).

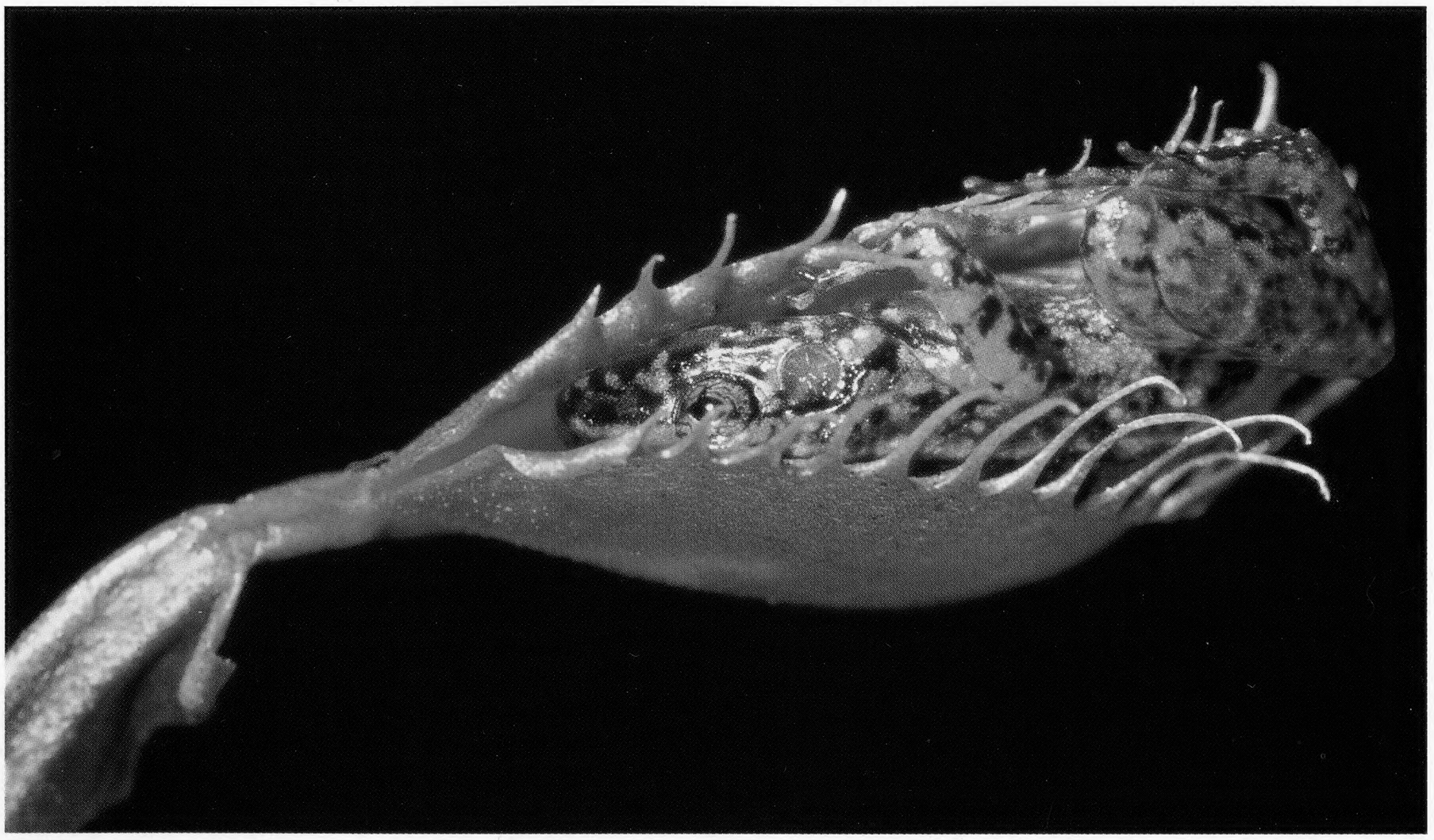
JOHN NETHERTON



DAN SUZIO

WESTERN TOAD (*BUFO BOREAS*).

ON WARM SPRING EVENINGS, SWAMPS, URBAN ponds, and even jungle movies are full of amphibian voices. Today, as when Mary Hinckley wrote in the 1884 *Memoirs of the Boston Natural History Society*, "As you approach a locality where [frogs] are in full voice, the air seems to grow gradually dense with this ear-deafening, all-pervading sound."



JOHN NETHERTON

A GREENHOUSE FROG (*ELEUTHERODACTYLUS PLANIROSTRIS PLANIROSTRIS*) STRUGGLES TO ESCAPE FROM A VENUS FLYTRAP.

For some people, frogs provide a delightful natural serenade. For others, they are an intolerable nuisance. In Panama, where I studied frogs and other amphibians for years, a friend stuffed rocks into the rain gutters around his house to stop the incessant singing of the túngara frogs (*Physalaemus pustulosus*), while I installed a pond outside our windows to attract these vocal creatures.

Frogs live in a wide diversity of places, and have evolved often extraordinary adaptations in appearance and behavior to face the challenges of their surroundings. While about 3,500 species of frogs (I use "frogs" to include toads, as I explain later) exist worldwide, including 25 in the state of Virginia alone, many people have actually seen, or heard, only a few. But their lives—and songs—deserve our full attention, as these marvelous creatures leap into an ever-changing world.

Perhaps to fully appreciate frogs, you need to understand why they are singing. Only male frogs sing. They do so to attract mates and warn off rivals. Female frogs use these songs to find males of their own species and select from among them the most attractive. Each species sings its own

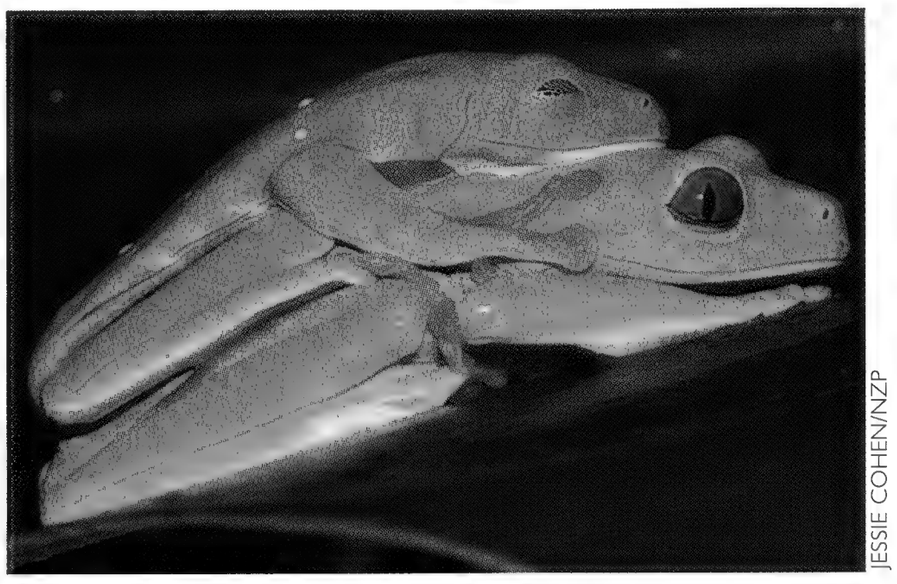
JOHN NETHERTON

THE PYGMY BANANA FROG, A NOCTURNAL SPECIES FROM TROPICAL AFRICA.

unique song, and with a little practice anyone can recognize all of the species in one's area.

The male frog's calls, given to attract females, may also attract the attention of predators. The fringe-lipped bat (*Trachops cirrosus*) in tropical America, for example, specializes in eating frogs. This bat locates its prey by listening for songs and, when it hears one, swoops down and picks the singer out of the water. A male túngara frog is caught between the risk of not attracting a mate if he does not call, and the risk of being caught by this bat if he does. As one line of defense, the frog adjusts his calls so that he takes the greatest risks from predators only when the risks of losing his mate to rivals singing nearby are highest.

Not all frog courtship is by singing. Frogs that live along mountain torrents, where calls can be lost in the sounds of the rushing water, may rhythmically wave their legs or arms to attract attention. Others emit a shrill whistle to be heard through the noise—like a doorman summoning a taxi. Once a pair has come together, the male and female touch and squeeze each other in a mating embrace known as amplexus, synchronizing the laying and fertilizing of eggs.



JESSIE COHEN/NZP

RED-EYED TREE FROGS (*AGALYCHNIS CALLIDRYAS*) IN AMPLEXUS.

Competition for mates may involve fights between rivals. An unmated male English toad (*Bufo bufo*) will try to displace a more fortunate male from the back of the female that he is clasping, but the intruder does not persist indiscriminately. If the warning squawk of the clasping male is high pitched—signaling that he is a small animal—the intruder perseveres, but if the call is deep—indicating a large male—the intruder leaves to search for a smaller rival. Fights over mates usually involve males, but in several species, like Panama's tic frog (*Eleutherodactylus diastema*), a female may attempt to displace another female during courtship by forcing herself under the male.

Males often defend not only their mates, but also their calling sites, against rivals. A male may use a special call to warn off another male that begins calling too close to him. If the intruder continues, the resident may attack him. Usually a trial of strength quickly determines who wins the calling site, but male gladiator treefrogs (*Hyla rosenbergi*) have sharp bony spurs on their thumbs with which they can injure a rival, even puncturing his eardrum.

Mating male toads (*Bufo* sp.) are particularly impetuous, occasionally forming a ball of squirming, croaking males, each attempting to force his way in toward the center. At the center of the toad ball is of course a female—but often a dead one killed by her overly enthusiastic suitors. Toad males, at the height of their breeding ardor, seem especially undiscriminating, and may grasp any nearby object of appropriate size: a frog, a dead rat, or the toe of a frog watcher's rubber boot.

Almost all frogs call by forcing air from their lungs through their larynx, causing the vocal folds to vibrate. This is much the same mechanism that we use to speak. But instead of exhaling to the outside as we do, a calling frog forces the air into an inflatable vocal sac. After the call is completed, the air is returned to the lungs to be used again. The vocal sac saves energy as well as air—critical to a male frog because calling is the most energetically expensive thing he ever does. Calling is so physically taxing that some male treefrogs abandon calling completely, instead sitting quietly next to a male that is calling, ready to intercept any female that approaches the caller. On any one night, these satellite males are less successful at getting mates than the callers, but they reduce the energy they expend, and lower their risk of predation, so that they can keep trying on future nights.

Frogs of different species lay their eggs in a

JOHN NETHERTON

JESSIE COHEN/NZP

AFRICAN BULLFROG (*PYXICEPHALUS ADSPERSUS*).

A male túngara frog is caught between the risk of not attracting a mate if he does not call, and the risk of being caught by a bat if he does.

JOHN NETHERTON

THE MALE GREEN TREE FROG (*HYLA CINEREA*) INFLATES HIS VOCAL SAC LIKE A BALLOON TO PRODUCE A LOUD QUANK-QUANK ADVERTISEMENT CALL.

diversity of sites: at the bottom of a pool or stream, attached to aquatic vegetation, floating in a foam nest, attached to a leaf overhanging the water, or away from the water, deep in a burrow or high in a tree hole. For many frogs, this is the extent of parental care. Once the eggs have been laid and fertilized, they are left on their own to develop. But some frogs exhibit more parental care than this, and do so in a variety of ways. In the completely aquatic Surinam toads (*Pipa pipa*), eggs are embedded in individual cavities in their mother's back where they develop and hatch as froglets. The mating pair must execute an intricate and precise maneuver to get the eggs laid, fertilized, and positioned correctly, because they do so without using their limbs.

JOHN NETHERTON

Instead of carrying her eggs on her back, the gastric-brooding frog female (*Rheobatrachus silus*) swallows them. The eggs develop in her stomach until they are vomited up as froglets. In Darwin's frog (*Rhinoderma darwinii*) in Chile, it is the male that takes the freshly laid eggs into his mouth, but instead of swallowing them, he maneuvers them into his vocal sac where they develop until they are ready to hop out. In the midwife toad (*Alytes obstetricans*), the male winds the string of eggs around his hind legs as they are laid and fertilized. When the eggs are ready to hatch, he hops awkwardly to the water where his offspring emerge and swim away as tadpoles.

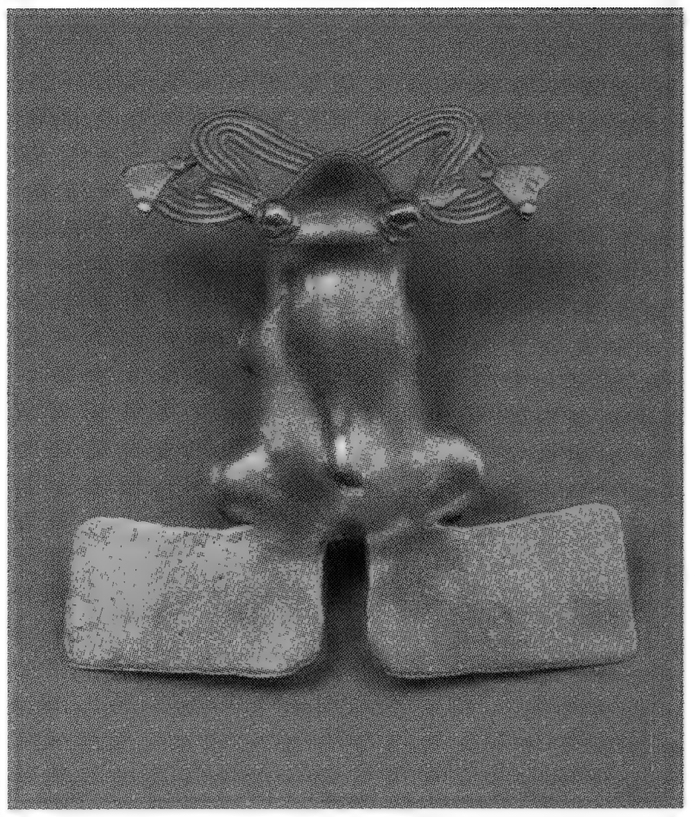
Female strawberry dart-poison frogs (*Dendrobates pumilio*) lay eggs in a curled leaf on the forest floor in Central America. The father tends the eggs, but, when they hatch, the mother carries the tadpoles on her back, one at a time, to tiny pools of water in the axils of large-leafed plants such as bromeliads. In these pools the tadpoles are safe from predators, but have little to eat. To feed them, the mother returns periodically to lay unfertilized eggs in each pool, providing the food the tadpoles need to grow and transform into frogs. African bullfrog (*Pyxicephalus adspersus*) fathers watch over their tadpoles as they develop, and if the pool in which his tadpoles are living should dry up, he digs an escape channel to a deeper and more permanent refuge.

It is because of their double life that frogs are called "amphibians." Typically they first live in the water as vegetarian tadpoles, and then move onto land as carnivores. (But not all tadpoles grow up in the water; some develop and transform into frogs before they hatch from the egg.) Tadpoles specialize in eating and growing. They feed mostly on plant material, scraping or biting bits off water plants, suctioning up detritus, or filtering microorganisms out of the water. Many take advantage of nutrient-rich temporary ponds that are relatively free of aquatic predators, particularly fish. In a few species, tadpoles are cannibals, specializing in eating other tadpoles, even individuals of their own species. Yet they choose tadpoles to which they are not closely related, in preference to eating their own siblings.

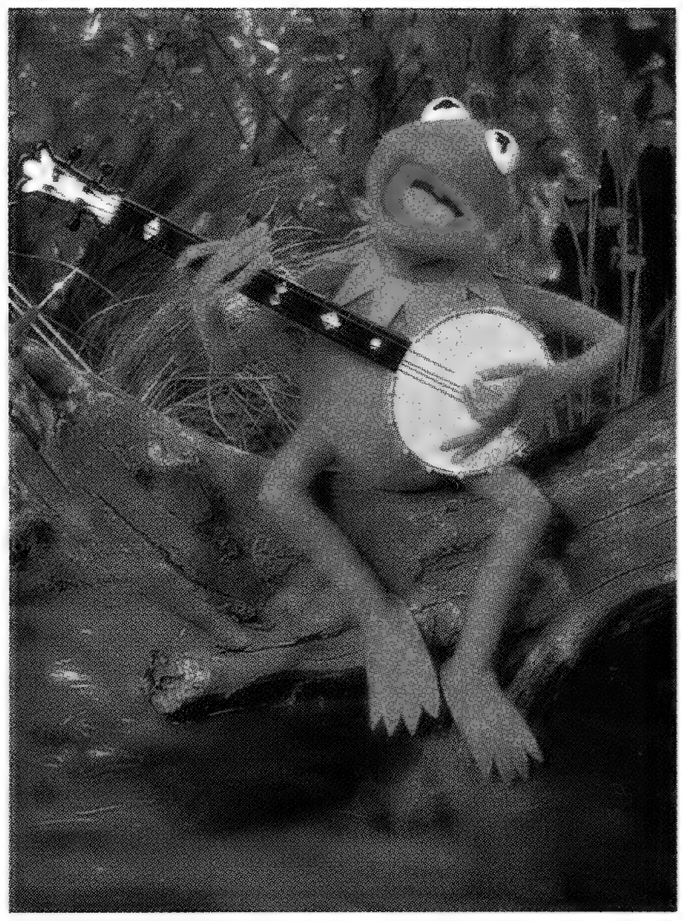
While tadpoles are largely herbivorous, the adult frogs they become generally make their living eating small animals: mostly insects, sowbugs, and worms. A few frogs are big enough to eat other frogs, as well as small lizards, mice, and occasionally a fish or a small bird. Usually, a frog catches its prey by flipping out its long sticky tongue and snatching it. Since frogs have very small teeth (if they have any at all), they don't chew their food, but swallow it whole—still alive and often still moving. I have seen a large grasshopper kicking in protest as it went down the gullet of a ravenous frog.

LEFT: THE GIRAFFE-LIKE PATTERNS ON THIS TREE FROG (*HYLA VULVOSA*) ALLOW IT TO BLEND INTO THE BARK AND LEAVES WHILE FORAGING FOR INSECTS. ABOVE: SEDGE FROG (*HYPEROLIUS PUNCTICULATUS*).

FROGS



THE METROPOLITAN MUSEUM OF ART, GIFT OF H. L. BACHE FOUNDATION, 1969. (69.7.4) PHOTOGRAPH © 1984 THE METROPOLITAN MUSEUM OF ART



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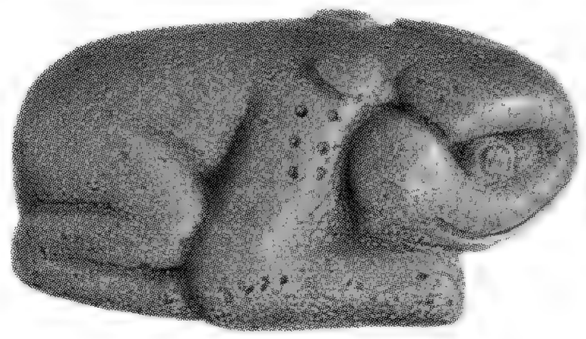


FROGS HOP INTO CULTURE AS DECORATIVE OBJECTS (TOP LEFT, BOTTOM RIGHT); AS PATTERNS IN THE MOLA ARTWORK OF PANAMA'S KUNA WOMEN (FAR RIGHT); AS A CAST-GOLD PENDANT FROM EARLIER PANAMANIAN CIVILIZATIONS (TOP); AND, OF COURSE, AS JIM HENSON'S LOVABLE KERMIT THE FROG.

Almost everywhere that there is frog food there are frogs. Frogs live throughout the tropic and temperate zones—anywhere from near-waterless deserts, to mountain torrents, to rainforest canopies—and their populations even straddle the Arctic Circle in Scandinavia and coastal Alaska. Because of their permeable skin, frogs are at risk from water loss. To avoid drying out, many frogs live in wet places. Most species are active at night when the air is more humid, and spend the day in damp hiding places. Those living in deserts dig down to moist soil and stay there until it rains—sometimes for months. When it does rain, the water-holding frog in Australia (*Cyclorana* sp.) absorbs enough water—up to half of its weight—to last through months, even years, of drought while sheltered in a cocoon-like chamber dug deep in the earth.

Burying yourself in the earth raises the problem of knowing when to emerge. Dwelling deep underground in the deserts of the southwestern U.S., spadefoot toads (*Scaphiopus* sp.) recognize that the rains have come by the vibrations of the drops hitting the surface above them. It has been reported that when off-road vehicles run over places where the toads are buried, the toads, tricked by the vibrations, dig up to the surface expecting to find water.

In contrast to the desert frogs, those that live along mountain torrents have too much water to deal with. Some tadpoles in these ecosystems have evolved large suckers on their undersides to climb spray-drenched cliffs and waterfalls, where they can graze on algae without being washed away. One place where you won't find frogs, however, is in the sea. Like slugs, frog skin can't stand salt, although the crab-eating frog (*Rana cancrivora*) of Southeast Asia can tolerate brackish water in its crab burrow lairs within mangrove swamps. Few native frogs, if any, are found on isolated oceanic islands like Hawaii.

Living in such diverse habitats, frogs have evolved a variety of sizes, shapes, and colors; but all are variations on a single theme. A frog may look like an unusual frog, yet it still looks like a frog. Nothing else looks even remotely froggish—not even frog fish, frog hoppers, or toad bugs.

Every frog has a short body without a neck or tail, and long hind legs. It is a body designed for jumping, although different kinds of frogs are specialized for different kinds of jumping. Just

ON WATERDOGS, MUDPUPPIES, AND THE OCCASIONAL HELLBENDER

BY ALEX HAWES

COAST RANGE NEWTS (*TARICHA TOROSA TOROSA*) IN AMPLEXUS

Frogs and toads aren't the only creatures leading double lives on land and underwater. While roughly 75 percent of the world's 4,500-plus amphibian species are indeed frogs, the class Amphibia does boast a wide assortment of other—often bizarre—life forms. Just take a gander at the Tennessee cave salamander (*Gyrinophilus palleucus*), a pale creature with a pinkish collar of gills, adapted for life in the cavernous pools of the Cumberland Plateau. Or the mysterious axolotl (*Ambystoma mexicanum*), an Aztec-named amphibian that lurks beneath the surface of Mexico's Lake Xochimilco—and there only. Or the worm-like caecilians, a little-understood group of burrowing amphibians from the tropics, growing up to five feet long.

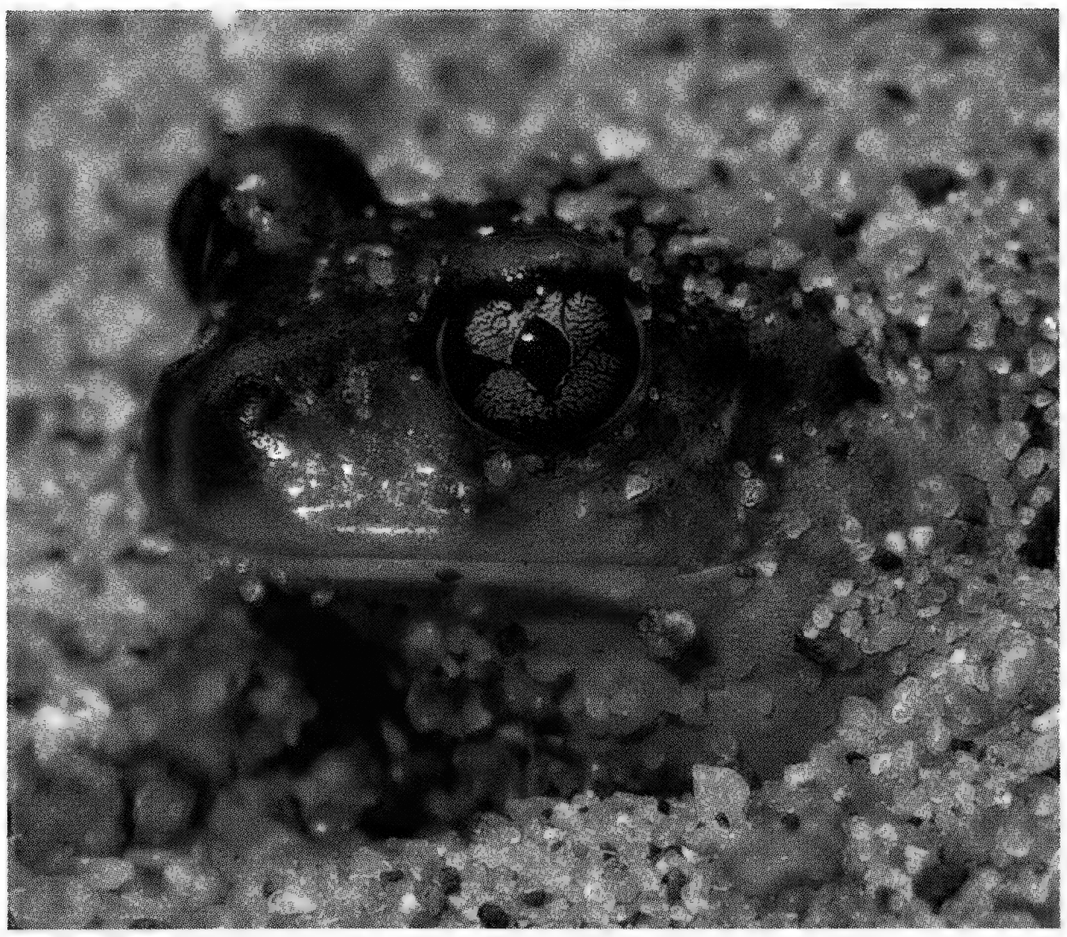
Apart from frogs and toads (order Anura), the remaining amphibians fall into either the order Caudata, which includes newts and salamanders, or the order Gymnophiona, the caecilians. All amphibians are ectothermic (cold-blooded), and require moisture for their sensitive skins. Anurans generally hatch as tadpoles in the water, then metamorphose into terrestrial-minded frogs and toads. However, many salamanders (including those species in the family Proteidae, labeled "mudpuppies" in the North and "waterdogs" in the South) adopt neoteny—maintaining their original, aquatic form throughout life. Most caecilians, on the other hand, skip the juvenile stage and hatch fully metamorphosed.

"Eye of newt and toe of frog, wool of bat and tongue of dog," begins the infamous recipe for the witches' brew in *Macbeth*. Newt eyes, however, are not terribly potent, visually speaking. Some newt and salamander species see quite poorly; others, like the rare Blanco blind salamander (*Typhlomolge robusta*), see not at all. Only the lungless salamanders (Plethodontidae) have the well-developed depth perception characteristic of mammals and birds. Instead, many salamanders, newts, and caecilians navigate via smell and touch. As opposed to their crooning frog cousins, salamanders and caecilians also remain fairly silent, capable only of the occasional click, snap, or "yelp," according to researchers.

In ancient myth, salamanders possessed skin so cold that it protected them from fire—perhaps a result of people witnessing salamanders escaping from burning logs. In truth, their skins may be slimy, but are hardly impervious. Amphibians do maintain a moist layer of film to protect against bacteria, to reduce friction when swimming, and even to slip away, literally, from predators. The skin of certain North American newts contains toxins of similar chemical composition to the poisons of pufferfish. These newts, however, are dangerous only through ingestion, not through contact—unless you have an open wound. Their toxins take effect only through the bloodstream. Such species often wave their tails about when threatened, luring predators to a spot where most of their toxins are concentrated. Fire salamanders (*Salamandra salamandra*) take a more proactive approach, squirting toxic secretions more than six feet to discourage foes.

The woods and wetlands of North America offer some of the best opportunities for discovering frogs' amphibian cousins. Of the nearly 400 species of salamander and newt, more species inhabit the New World than all other regions combined, including all 230 or so species of lungless salamander. The United States and Canada alone support more than 150 species of newt and salamander, ten of which are currently listed as threatened or endangered. (No caecilians, however, live in North America.)

Salamander numbers can be staggering if you know where to look. In one Texas pond, the combined weight, or biomass, of the lesser sirens (*Siren intermedia*)—an aquatic salamander two feet in length—was found to exceed the total biomass of the pond's seven species of fish. Researchers surveying Shenandoah National Park one wet night encountered a density of up to ten redback salamanders (*Plethodon cinereus*) per square meter. But if squishing through swamps and turning over logs isn't your idea of fun, the National Zoo's Reptile Discovery Center hosts three-toed amphiumas (*Amphiuma tridactylum*) and Eastern hellbenders (*Cryptobranchus alleganiensis alleganiensis*), while at Amazonia you'll find aquatic caecilians (*Typhlonectes natans*) in Dr. Brasil's Field Station.



JOHN NETHERTON

EASTERN SPADEFOOT TOADS (*SCAPHIOPHUS HOLBROOKII HOLBROOKII*) ESTIVATE UNDERGROUND FOR WEEKS AT A TIME, AWAITING RAIN.

FROG CURIOS.

as you can distinguish professional football players from basketball players by their physiques, you can pretty well predict how a frog will jump from its form. A frog's long hind legs provide the propulsion in its jump. Generally, the longer the legs, the longer the jump. If you ever lay a bet on a frog jumping contest, you should pick the frog with the longest legs. However, if you ever wager on a frog marathon, where endurance is at a premium, bet on the short-legged frog.

Among terrestrial vertebrates, frogs and their amphibian cousins are unique in their permeable skin and wide assortment of tightly set glands. These glands keep the skin moist, even slimy, and provide the poisons for defense against both predators and infections. A frog is not completely dependent on its lungs to pick up oxygen and get rid of excess carbon dioxide, as we are. Being permeable, a frog's skin can be used for respiration too. Yet this permeability, while advantageous for respiration, makes frogs particularly sensitive to airborne and waterborne pollution. And pollution is an increasingly serious problem for amphibians around the world, even for those in apparently pristine environments (see following article).

The answer to a question I am often asked, "What is the difference between frogs and toads?" lies in their skins. "Frog" and "toad" are both names that developed in England, where there exist only two sorts of tailless amphibians: slippery, long-legged ones called "frogs," and dry-skinned, short-legged ones called "toads." However, elsewhere in the world are found many other kinds of tailless amphibians that don't look like either English frogs or toads. I label them all "frogs," and call only the dumpy, dry-skinned ones "toads." So the short answer to the question is: "A toad is a dry frog."

Most frogs are camouflaged to avoid capture by predators, or detection by prey. Frogs that sit on leaves in the canopy, for example, are usually green, while those that burrow in the ground are earth-colored, and those that live on the floor of a tropical forest look like dead leaves. Individuals within a species can also vary greatly in pattern and color, making it hard for a predator to learn to recognize its prey. Even a naturalist can be fooled. A primatology student, who spent his days in Panama following white-faced capuchin troops, often brought me frogs for identification. For about a week straight, he presented me

JOHN NETHERTON

THE COLORATION AND LEAF-LIKE HORNS AND SNOUT OF THE ASIAN LEAF FROG (*MEGOPHRYS NASUTA*) PROVIDE CAMOUFLAGE AMID THE FOREST LITTER.

Panamanian common toads (*Bufo typhonius*), one after another, each individual so distinct in color and markings that he mistook them for separate species.

People have been interested in frogs for a long time. During excavations of a pre-Columbian village in the central provinces of Panama, my colleague, Smithsonian Tropical Research Institute archeologist Richard Cooke, found a collection of giant toad bones (*Bufo marinus*). To find out if the people who made the pits could have been eating the toads and then tossing out the bones, one of our graduate students organized a tasting. He deep-fried both frog legs and toad legs and presented them as canapés to a group of blindfolded Smithsonian secretaries, scientists, and students. After sampling both toads and frogs, we concluded that pre-Colombian gourmands might have eaten toads, but certainly would have preferred frogs.

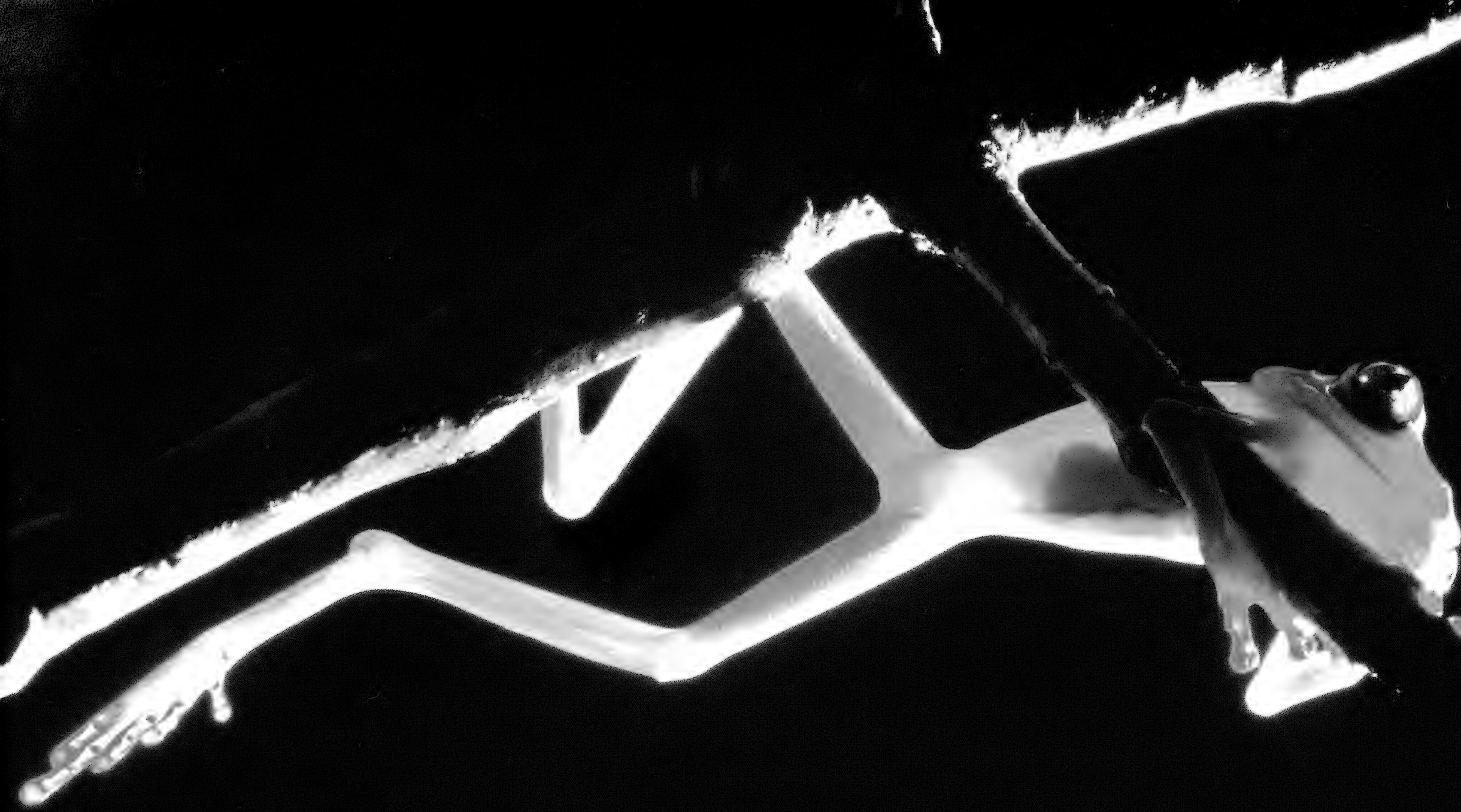
Even nowadays, people who are not naturalists may encounter frogs in their daily lives. Humans use frogs as food, as pets, as medicine, and as decorations. When you work with frogs, as I do, people give you things in the shape of frogs. Every shelf in my office has frogs on it: a frog phone, a frog stapler, a frog letter opener. A frog mouse pad sits by my computer, and a frog calendar hangs above it.

More practically, frogs can act as biological control agents. They eat lots of insects, including agricultural pests and potential carriers of disease. Indian farmers defend their frogs for this reason. Once, while walking through a flooded rice paddy in central India, I grabbed one of the jumping frogs that dotted the paddy for a closer look. Anxiously, my guide warned me: "Be careful! If the villagers see you hurt a frog, they will stone us to death! They believe that frogs eat the malaria mosquitoes that breed in the flooded fields, and they are very serious about protecting them." I set the creature down gently, thinking it wise not to challenge such frog protectiveness.

Although they have been replaced by kits from the local drugstore, frogs were once widely used in pregnancy tests. In the days when giant toads were used in Panama's public health clinics, a woman was expected to bring her own toad. I remember seeing small boys at the bus stop outside the Santo Tomas hospital toting cardboard boxes of toads for sale to women who had come without one.

> When off-road vehicles run over places where the toads are buried, the toads, tricked by the vibrations, dig up to the surface expecting to find water.

Many frogs have poisonous skin for their own defense, and in the Choco rainforests of Colombia there are a few frog species (*Phylobates* sp.)—bright yellow, and very poisonous—that are actually used by indigenous hunters to treat blowgun darts. Upon finding one such frog in the forest, a hunter pins it to the ground with a stick, and pulls his dart across its back a couple of times. He then has enough venom on his dart to kill a monkey, and probably a man. Scientists on an American Museum of Natural History



JOHN NETHERTON

JOHN NETHERTON

GOLDEN MANTELLA (*MANTELLA AURANTIACA*).

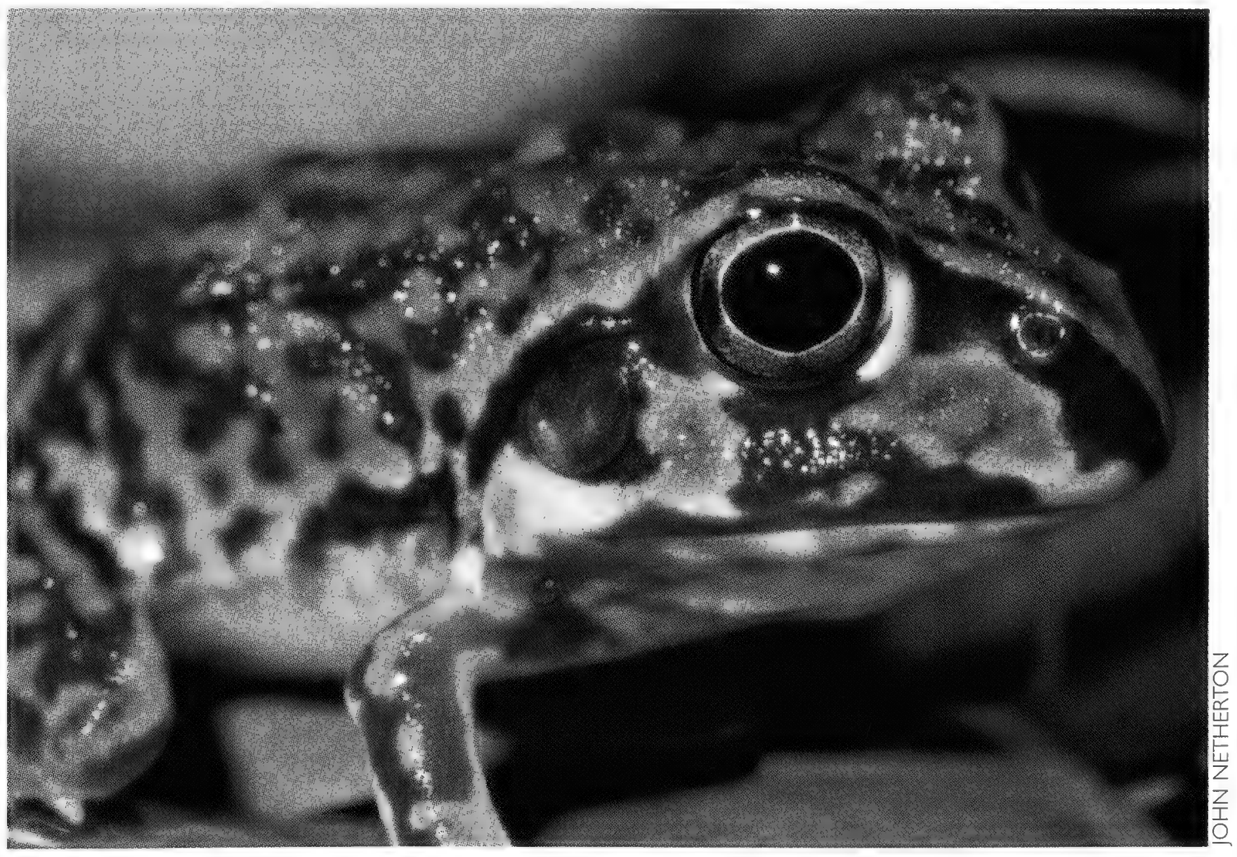
"Frog" and "toad" are both names that developed in England, where there exist only two sorts of tailless amphibians: slippery, long-legged ones called "frogs," and dry-skinned, short-legged ones called "toads."

expedition visiting these Indians in the 1960s reported finding frogs with thin black lines across their backs—scars from being used to poison a dart. Medical researchers are studying the toxins produced by some of the "dart-poison" frogs for possible use in the treatment of human disease.

Today, the United States is a major international market for frogs. In addition to frogs imported as food, the U.S. Fish & Wildlife Service import summary for 1998 reported that some 15 million small frogs were imported alive into the U.S. that year, presumably for the pet trade. Overexploitation of frogs as pets is probably not nearly as threatening to frog populations as habitat destruction is. However, one serious consequence of the frog trade is the risk that imported individuals may bring in diseases that infect wild, native species. Recent studies indeed show that disease is a major factor in the decline of many frog populations.

The enthusiasm for keeping frogs as pets is new in the U.S., but has existed in Europe for some years. Once, friends took me to visit the apartment of a Parisian frog enthusiast who had covered one wall of his living room with burlap, upon which he hung orchids and bromeliads. A recirculating pump kept water spraying onto the plants, as West Indian treefrogs (*Eleutherodactylus johnstonei*) climbed and sang amid the verdant flora. When the man asked his neighbors if the frogs bothered them, they told him no, but that they were annoyed by somebody in the building playing loud video games all night. The man chose not to inform them that they had been hearing the electronic-sounding songs of his pet treefrogs.

We frog enthusiasts often have favorite species. Many people find the red-eyed treefrogs (*Agalychnis callidryas*) so often seen on T-shirts beautiful. I have a personal preference for the less garish frogs with clean lines and bold patterns, like *Colostethus talamancae*, a small, brown frog with yellow racing stripes. Yet the most dazzling frog spectacle I have ever witnessed was the sight of orange dart-poison frogs (*Dendrobates speciosus*) hopping over a blanket of bright green moss jeweled with dewy mist, beneath the lush cloud forest canopy of western Panama. Beauty can depend on the beholder's circumstances, however. A mudbrown toadlet (*Physalaemus* sp.) hidden under a dead leaf is truly ravishing when I finally catch him in my headlight—after spending half an hour following his calls in the rain—and realize that he is a species new to me, and perhaps new to science.



JOHN NETHERTON

NORTHEASTERN WATER-HOLDING FROG (*CYCLORANA NOVAHOLLANDIA*).

Frogs' fabled tales and appearances as stuffed toys and ceramic ornaments have hopped into the consciousness of cultures around the world. But with their pervasive voices and fascinatingly varied natural histories, frogs themselves well repay study, particularly as their populations—from the high Sierras of California to the rainforests of Queensland—are dwindling. I hope that an understanding of the dazzling rainbow of frog species, and of the spectrum of their songs and stories, will help encourage their conservation—and keep them singing. Z

A. Stanley Rand, Senior Biologist Emeritus at the Smithsonian Tropical Research Institute, studies both amphibians and reptiles.
John Netherton's wide array of frog photos are featured in the Voyageur Press book Frogs, *on sale in the National Zoo Bookstore.*

WHILE HIDING DURING THE DAY, THE GLASS LARGE-EYED FROG (*LEPTOPELIS BOCAGII*) DRAWS ITS LONG LIMBS IN, ASSUMING AN ELLIPTICAL SHAPE LIKE A LEAF.

JOHN NETHERTON

Chasing Frogs and Phantoms:

The Mystery of Amphibian Declines

BY HOWARD YOUTH

ON AUGUST 8, 1995, TEACHER CINDY REINITZ AND EIGHT MINNESOTA NEW COUNTRY MIDDLE SCHOOL STUDENTS WERE PADDING DOWN A FARM ROAD ON THEIR WAY TO AN OUTING IN THE NEARBY NEY WOODS. "WE WERE JUST GOING TO NATURAL AREAS AROUND OUR COMMUNITIES, SO THE KIDS COULD UNDERSTAND AND APPRECIATE WHAT THEY HAVE IN THEIR BACKYARDS," RECOUNTS REINITZ. "BUT WE NEVER MADE IT TO THE WOODS."

THE FRAGILE FROG OFFERS A WINDOW INTO THE FAINTLY VISIBLE FORCES OF ENVIRONMENTAL CHANGE.

At a section of the road bordered by a corn field on one side, a bean field on the other, the students caught sight of scores of northern leopard frogs (*Rana pipiens*) hopping about a nearby pond. They interrupted their walk and began diving for frogs, playing a game of catch-and-release. But then a child stumbled upon a troubling find, the first clue in one of the greatest ecological mysteries of our time.

"One student found a frog with one very, very thin leg. Just bone covered with skin, no muscle—very strange," says Reinitz. "I thought it had gotten hurt with the kids belly-diving for the frogs." Shortly thereafter, however, another student discovered a frog missing a hind leg.

Deciding that the situation merited better data, the students captured a total of 22 frogs. Half of them were deformed. "That just didn't seem like it was a normal thing," recalls Reinitz. Some students wanted to keep the frogs to show scientists. Others wanted to leave them unmolested. "We compromised and decided we'd take three of the most grotesque ones back in an ice-cream bucket."

Reinitz soon linked up with a Minnesota Pollution Control Agency scientist, and from there life got crazy. Reporters, satellite trucks, and scientists from all around descended upon sleepy Henderson, Minnesota, and its "mutant frog" pond. Deformed frogs were soon reported from two-thirds of the counties in Minnesota, and in other states. The inevitable question was raised by scientists and journalists alike: What could be disfiguring so many frogs? Studies began almost immediately to look for answers—from pesticides and heavy metals to parasites, ultraviolet light, viruses, or just natural causes. But almost five years later, no clear explanations have emerged.

Frog deformities have been documented in different parts of the world for more than two centuries. But the sheer number of deformed frogs found in Minnesota alarmed scientists, and highlighted heightened global concerns over mysterious amphibian declines and disappearances plaguing various regions of the world. Many scientists now think multiple factors come into play to create amphibian deformities and declines. And declines and deformities, they caution further, are not necessarily linked.

MINNESOTA POLLUTION CONTROL AGENCY

ONE OF THE LESS GROTESQUE FROG DEFORMITIES.

Something in the Air?

The planet's hopping and crawling amphibians, biologists believe, can provide valuable insight into the health of their larger ecosystems. Most species of frogs, toads, and salamanders lead double lives, starting out as aquatic eggs and larvae and later switching to a terrestrial adulthood. Their development thus puts them in contact with two potentially polluted habitats. Also, many amphibians breed in small pools, then disperse after breeding to more far-flung haunts. Migrations to and from breeding pools are often cut short by the fragmentation or destruction of their habitat.

But researchers seeking answers to ecological whodunits especially prize amphibians' extremely sensitive skin. "Skin changes that would be considered relatively minor in a mammal, bird, or reptile can have highly significant effects in an amphibian," says National Zoo associate pathologist Don Nichols. "Amphibians rely on their skin to absorb water, and to control hydration and the concentration of some important minerals in the bloodstream. Also, to a certain degree they breathe through their skin, and it plays a role in temperature control," says Nichols.

According to the World Conservation Union's 1996 Red List of Threatened Animals, 25 percent of amphibian species for which ample data exist are classified either as endangered or vulnerable. The United States and Australia house the most species listed as such—about two dozen each—but that fact probably disguises the paucity of data from tropical countries, where the most species live and where habitat destruction is most rampant. Only 12 of the United States' 17 amphibian species currently listed as endangered or threatened have recovery plans.

While habitat destruction undoubtedly constitutes one of the greatest threats to the world's amphibians and other wildlife, scientists are puzzled over inexplicable amphibian declines in more remote and seemingly pristine areas, including, for example, Monteverde Cloud Forest Preserve in Costa Rica. Established in 1973, Monteverde now protects 26,000 acres of cloud forest. The preserve, however, did not protect one of its greatest treasures: the world's only known population of the gaudy golden toad (*Bufo periglenes*). In 1987, golden toads suddenly vanished even from the heart of the refuge. Surveys of the region in the early 1990s revealed that the golden toad disappearances were not an isolated incident. Twenty of 50 frog and toad species in a 7,400-acre study

THE NOW-EXTINCT GOLDEN TOADS (*BUFO PERIGLENES*) AT A BREEDING POOL IN COSTA RICA'S MONTEVERDE CLOUD FOREST PRESERVE.

area lying mostly within the preserve had disappeared without a trace.

Researchers believe that the world changed around these moisture-dependent, mountain-dwelling animals. Global warming likely played a role in their population crashes, which occurred abruptly in 1986 and 1987 during extremely warm, dry conditions. In a 1999 study published in the journal *Nature*, biologists J. Alan Pounds, Michael P.L. Fogden, and John H. Campbell wrote, "Our results indicate that these crashes probably belong to a constellation of demographic changes that have altered communities of birds, reptiles, and amphibians in the area and are linked to recent warming." Amphibians, they found, declined more dramatically than any other group. The scientists hypothesize that atmospheric warming raised the height at which condensation begins, so that higher clouds may now pass high over Monteverde, instead of dragging across the forest depositing mist. Meanwhile, there's been no sight of the golden toad, and no better hypotheses have emerged to explain its disappearance.

Acid precipitation is a more clear-cut threat to amphibians living in or near industrialized regions. For example, sulphur dioxide emissions from power plants and nitrogen oxides from car exhaust—which can raise acidity levels in breeding pools—have been blamed for the virtual

disappearance of natterjack toads (*Bufo calamita*) in southern England. In 1997, researchers examining northern leopard frogs concluded that acidified waters also lower frogs' resistance to a form of bacteria that can colonize their spleens, and kill them.

JESSIE COHEN/NZP

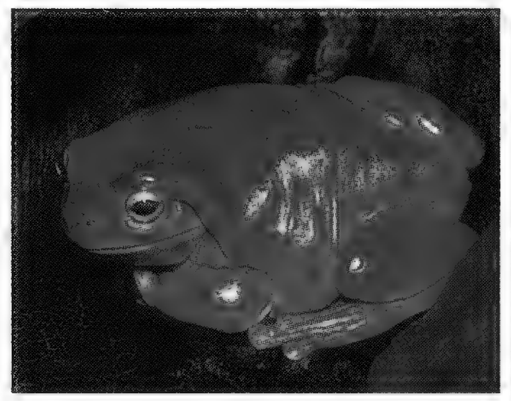
BLUE DART-POISON FROG (*DENDROBATES AZUREUS*).

Finding New Enemies

Another malady linked with amphibian declines is a mysterious disease caused by the chytrid fungus *Batrachochytrium dendrobatidis*, the first such fungus known to harm vertebrates. Don Nichols began seeing the strange affliction back in 1991, when the Zoo received samples taken from a captive colony of dying arroyo toads (*Bufo microscaphus californicus*) in California. "It was a unique skin disease, unlike anything I'd seen before, associated with infection by these strange round, microscopic organisms," says Nichols. On and off over the next five years, he received samples, searched the literature, and consulted experts, but it wasn't clear exactly how to classify the organisms causing the disease: Were they algae, protozoa, or fungi?

When the disease hit the Zoo's White's tree frogs (*Litoria caerulea*), blue dart-poison frogs (*Dendrobates azureus*), and green-and-black dart-poison frogs (*Dendrobates auratus*) in 1996, Nichols and Allan Pessier, a resident in the Zoo's Department of Pathology, were able to collect fresh samples. After results of electron microscopic examinations suggested the organism might be a chytrid fungus, Pessier searched the Internet and found one of the world's few chytrid experts, Joyce Longcore at the University of Maine, who confirmed their suspicion. Meanwhile, having verified that the chytrid fungus indeed caused the disease, Nichols and Department of Pathology biologist Elaine Lamirande found ways to treat the Zoo's ailing frogs.

"This type of fungus had never been considered to be pathogenic," says Nichols, "so you couldn't find it in the veterinary literature. But here was a new chytrid that affects vertebrates—that was unheard of."



JESSIE COHEN/NZP

WHITE'S TREE FROG (*LITORIA CAERULEA*).

Troubling news soon came from the field: Frogs and toads were turning up with the disease in distant corners of the globe. In 1997, a veterinary pathologist named D. Earl Green told Nichols of samples of wild frogs and toads he received that had been found dead and dying in Panamanian streams. Soon after, word came that Australian scientists Rick Speare and Lee Burger were tracking a pathogen sweeping through the continent's wild frog and toad populations. This killer is now considered among the possible causes in the decline or disappearance of at least 14 frog species in Queensland rainforests. While Nichols and his colleagues worked to identify the disease in Zoo amphibians, Green, Speare, and Burger studied the wild populations. "We all were coming to the same conclusion," says Nichols.

Although the culprit now has a name and classification, it remains very much an enigma. Nichols doubts the fungus is the sole killer. "It doesn't do a parasite any good to kill its host. Other factors may be tipping the balance," he says. "Something in the environment may have changed. These are all things that need to be sorted out."

Another question without an answer so far: Where did it come from? "This thing's popping up all over the place—in zoos, wild leopard frogs in Arizona, boreal toads [*Bufo boreas boreas*] in

Rocky Times for a Rocky Mountain Toad

One of the amphibians most vulnerable to the chytrid fungus is the boreal toad (*Bufo boreas boreas*), a blotch-bellied amphibian found from southeast Alaska to Colorado and northern California. Over the past 20 years, the southern Rocky Mountain population, now listed as endangered in Colorado and in New Mexico (where none are known to remain), has sharply declined around the lakes, ponds, and streams where they were once common. In 1999, Colorado Division of Wildlife biologists, who had been monitoring their state's dwindling toads for a decade, found animals afflicted with the chytrid fungus for the first time, at a study site west of Denver.

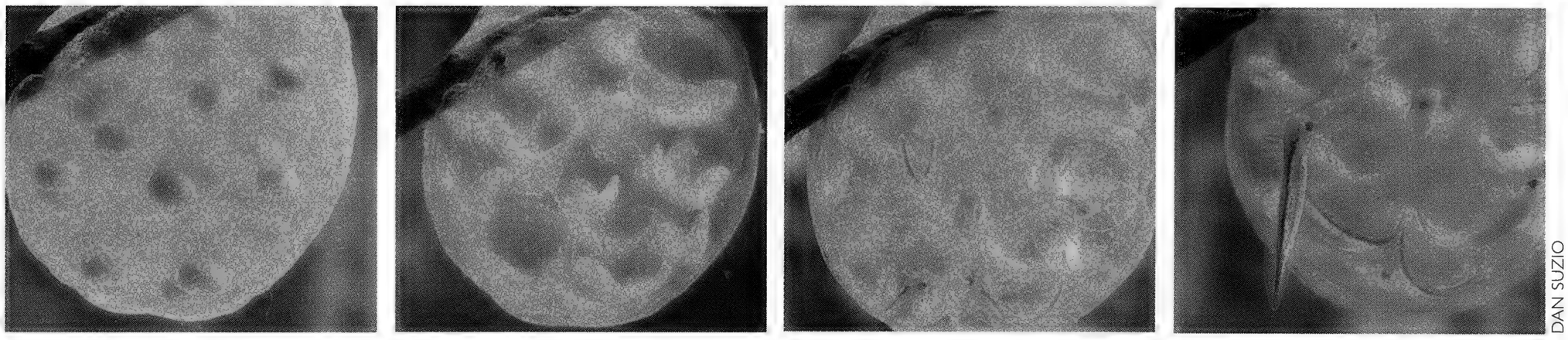
Meanwhile, federal biologists are monitoring a decline in boreal toads living in the nearby Rocky Mountain National Park. "We've witnessed fairly precipitous declines at what have in the past been two of the most robust sites in the state," says U.S. Geological Survey (USGS) zoologist Erin Muths. "We didn't see declines in both sites until this year. These are spots in national parks, and they're considered back country—they're not polluted or over-used. We don't have an easy explanation for the decline," she says. "In fact, that's the million-dollar question."

After the state biologists discovered chytrid fungus in their toads, Muths and her colleagues tested the park's toads, and detected the fungus too. In 1999, the biologists caught fewer than ten toads at one of the park sites where they had previously caught up to 200. "My guess is that the decline of boreal toads in Rocky Mountain National Park is a combination of less obvious environmental stressors working in concert with this newly identified disease," says Muths.

She and her colleagues track the toads with tiny transponders the thickness of a pencil, hoping to learn more about the toads' habitat use and about other aspects of their life history. "We're going to keep on monitoring," says Muths. "It's important to see patterns over time. That's what's missing globally—identification of the long-term patterns."

—Howard Youth

COAST RANGE NEWT LARVAE AT TWO DAYS OF DEVELOPMENT, 11 DAYS, 19 DAYS, AND THEN NEWLY HATCHED FROM THE EGG CLUSER. AMPHIBIANS SUCH AS THESE NEWTS ARE VULNERABLE TO POLLUTANTS BOTH ON LAND AND IN THE WATER.

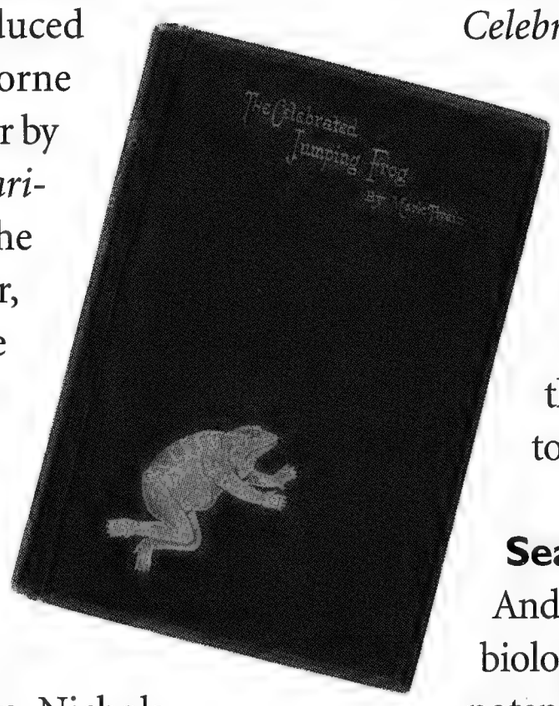


DAN SUZIO

Troubling news soon came from the field: Frogs and toads were turning up with the disease in distant corners of the globe.

Colorado," says Nichols. "How did it get all over the place, and apparently suddenly? There don't appear to have been cases before the late 1980s."

Evidence from Australia points to an introduced pathogen possibly borne by escaped pet frogs, or by giant toads (*Bufo marinus*) introduced in the 1930s (see sidebar, p.27). "For all we know, researchers could be carrying it in on their boots, going from swamp to swamp and carrying it from place to place," says Nichols. Increasingly, biologists disinfect their field equipment after visiting research sites—but that was unheard of ten years ago.



While fungi present a clear problem, scientists also believe viruses may play a role in amphibian declines. For example, tiger salamander (*Ambystoma tigrinum*) die-offs in Utah and Maine in 1998 might have been the handiwork of a killer iridovirus, like the one thought to have caused earlier tiger salamander die-offs in Arizona and Saskatchewan. And in 1999, a study in California showed that both wild stickleback fish (*Gasterosteus aculeatus*) and the now threatened red-legged frogs (*Rana aurora*) carry the same iridovirus.

This finding disturbs conservationists trying to save the red-legged frog, the western United States' largest native species, and the species Mark Twain likely had in mind in his novel, *The Celebrated Jumping Frog of Calaveras County*.

Researchers already knew that introduced trout, bass, sunfish, large minnows, and bullfrogs (see sidebar, p. 27) consumed and out-competed native frogs and California newts (*Taricha torosa*). But the new finding indicates that the introduced species may spread disease to them as well.

Searing Sun and Strange Brews

Andrew Blaustein, an Oregon State University biology professor, has long sought to pin down potential causes for the precipitous declines of western amphibian species. In a 1994 study, Blaustein and his colleagues offered one answer. Natural ultraviolet (UV) light, they found, was killing the eggs of declining Cascades frogs (*Rana cascadae*) and western toads (*Bufo boreas*), but not those of the stable Pacific treefrog (*Hyla regilla*). (The Pacific treefrog apparently produces more of an enzyme that enables it to heal from UV-caused damage.) Dozens of experiments and papers have since focused on the implications of ozone-layer depletion—which leaks UV light into our atmosphere—for amphibians elsewhere.

"We now know that a good couple of dozen species are affected by UV," says Blaustein. "From our studies, we know it's lethal in Cascades frogs, western toads, long-toed salamanders [*Ambystoma macrodactylum*], and northwestern salamanders [*Ambystoma gracile*]." Research has also uncovered non-lethal effects of UV exposure, says Blaustein, including the discovery that frogs that bask in sunlight are more likely to suffer damaged retinas.

Scientists are particularly concerned with how elevation, water depth, and water chemistry affect UV penetration. Steve Corn, a U.S. Geological Survey zoologist at the Montana-based Aldo Leopold Wilderness Research Institute, studies how UV exposure varies between amphibian habitats and over time. Ultraviolet radiation, Corn says, increases during the spring, remains high in summer, and then declines in the fall. "But that varies year to year due to weather," he says. "The UV reaching the surface is pretty variable, and amphibian breeding is also variable, sometimes ranging from 30 to 45 days from one year to the next."

Blaustein is also looking into another troubling link—that between amphibian declines and fertilizers. In a 1999 study, he and his colleagues demonstrated that even at very low doses—lower than E.P.A. standards allow for drinking water—fertilizer damaged larval stages of the Oregon spotted frog (*Rana pretiosa*), a species declining throughout its range. Blaustein and his colleagues also concluded that fertilizers building up in water also encourage algae growth that benefits parasitic flatworms called trematodes. Trematodes cause frog deformities by boring into larvae and adults,

forming cysts that disrupt limb development. Blaustein and other scientists are further trying to understand if there is a link between UV exposure and lowered resistance to pathogens in amphibians.

Chemicals are also under scrutiny. U.S. Geological Survey (USGS) toxicologist Don Sparling and his colleagues have studied the effects of methoprene, an active ingredient in the insecticide Altosid, which is used to control mosquitoes in many areas, including some national wildlife refuges. Using a series of room-sized experimental wetlands at the Patuxent Wildlife Research Center in Laurel, Maryland, the researchers found that 15 percent of southern leopard frog tadpoles (*Rana utricularia*) hatching in sprayed pools had deformities, compared with 4.5 percent of tadpoles in unsprayed, control pools. Sparling says there is also strong evidence implicating methoprene in the delayed maturation and development of southern leopard frogs and northern cricket frogs (*Acris crepitans*).

Sparling and other scientists are collecting data that they believe could soon prove that the widely used insecticides malathion and chloropyrifos are harming Sierra Nevada amphibian populations just east of California's heavily agricultural Central Valley. Even more toxic than these compounds are chemicals called pyrethroids—insecticides that can prove lethal to amphibian larvae at dilutions as low as one part per million. But in a literature search for an upcoming book, Sparling and his colleagues found only 221 studies on the effects of contaminants on amphibians, compared with some 7,000 such studies for fish. "There's a great need for additional research on amphibians," argues Sparling.

Human activities can affect amphibian populations more directly than the insidious forces of disease, climate, and chemistry. About 10 to 12 million wild frogs are caught each year for dissection in U.S. classrooms, while the French alone annually consume six to eight million pounds of frog legs—many imported from Asia and other parts of Europe. Yet habitat destruction has a far greater impact. A 1993 study in western North Carolina concluded that it takes 50 to 70 years for forest salamander populations to recover after their habitats are clearcut, and that an estimated 14 million salamanders have died from clearcutting in the national forests of western North Carolina. Habitat fragmentation by roads also takes a toll. For example, 43 percent of young southern leopard frogs observed emerging from one Florida pond were mowed down by cars upon leaving their natal pool.

JOHN NETHERTON

HARLEQUIN FROGS (*ATELOPUS FLAVESGENS*) DECLINED IN COSTA RICA'S MONTEVERDE CLOUD FOREST PRESERVE AT THE TIME OF THE GOLDEN TOAD'S EXTINCTION.

Hopping to It

Much remains to be learned about amphibians and the causes of their declines and deformities. Long-term data are lacking for most populations, partly because amphibians haven't traditionally received nearly as much attention as is lavished upon fish, large mammals, or birds.

But that is quickly changing. The Declining Amphibian Populations Task Force (DAPTF), founded by the World Conservation Union's (IUCN's) Species Survival Commission in 1990, is bringing together amphibian researchers from around the world. "It's been amazingly successful in serving as the nervous system for the declining amphibian phenomenon and getting information into one central location, then distributing it back out," says DAPTF chair Ron Heyer, a research curator at the Smithsonian National Museum of Natural History's division of amphibians and reptiles.

DAPTF provides seed grants to researchers in foreign countries who focus on amphibian declines. Yet until a few years ago, even many North American amphibians escaped scrutiny. Now several programs are seeking to build much needed long-term data sets on frog, toad, salamander, and newt populations. In 1996, the USGS launched a continent-wide monitoring effort called the North American Amphibian Monitoring Program (NAAMP). The program's first component, a frog call survey, is modeled after the USGS's long-standing Breeding Bird Survey. A federal, interagency amphibian monitoring program also begins this year in 11 national parks and in some national wildlife refuges.

"It's as close as you're going to get of an idea of what's happening all over the whole patchwork of U.S. and Canadian landscapes," says NAAMP coordinator Linda Weir, who works with states and provinces to set up monitoring programs to coordinate data collection and recruit volunteers. (No Mexican monitoring routes have yet been assigned.) So far, 29 states have come on board, using 1,000 to 2,000 volunteers

to cover about 1,000 roadside routes. Volunteers go out three to four times a breeding season to ensure they hit their routes during the breeding peaks of different species. A similar program recently began in Australia, while regular monitoring programs have been ongoing in Great Britain and in parts of continental Europe.

"I think the general public is more concerned about amphibians than most people realize," says Weir. The USGS is also tapping this concern through its Frogwatch program, which encourages volunteers to monitor a selected backyard or neighborhood pond. Meanwhile, an amphibian monitoring program has just begun at the Zoo's Conservation and Research Center (CRC) in Front Royal, Virginia. "We hope to develop a network of science teachers, school science clubs, and young naturalists who will work together to establish a continuous, long-term monitoring of local amphibian populations in ponds and streams," says Chris Wemmer, the Zoo's associate director for conservation. Teacher workshops are just beginning, and the program is being launched in the seven counties nearest CRC.

"We're particularly interested in getting kids to learn to love nature," says Wemmer. "You've got to do more than surf the web and watch TV if you want to make deep connections—you have to have personal involvement in the real world of nature. That's what this is all about."

Five years ago, it was exactly such a connection that inspired eight students to dive after frogs in a Minnesota farm pond. "It's been a wonderful lesson for the kids to see that answers aren't always clear-cut and quick," says Reinitz.

Some of the students continue to investigate the frog puzzle. "It's also great that such an important ecological question was brought to the forefront by kids," says Reinitz, "and that they can know that not all great discoveries have been made. That's why I encourage them to always keep asking." Z

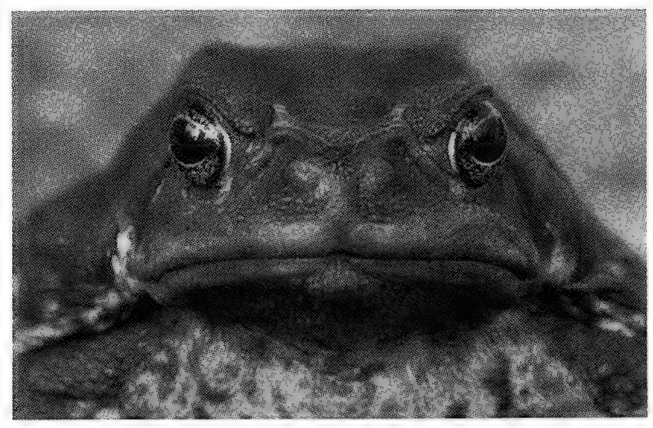
—Howard Youth is a Contributing Editor to ZooGoer.

Dan Suzio is a California-based photographer who specializes in reptiles and amphibians. His work (seen on pages 8,15,25) may be seen on the web at www.suziophoto.com

AMPHIBIAN INVADERS: DOWN UNDER AND ALL AROUND

Not all amphibians are suffering declines. Some, in fact, are flourishing in places they don't belong—and causing serious ecological problems. Consider the giant toad (*Bufo marinus*), originally a native of French Guiana in South America. Now probably the world's most widely introduced amphibian, this cow-pie-sized eating machine was carried to various sugar-growing countries—including many Caribbean islands, Australia, Taiwan, Japan, the Philippines, and the Micronesian islands—to dine on crop-eating beetles. Ugly and loud (choruses remind some of idling diesel engines), giant toads—or cane, or marine toads as they are also known—gobble down almost anything that strays before them, including native wildlife.

Giant toads also are highly toxic. Predators often die after biting into the bulging, poisonous parotid glands that sit behind the toads' eyes. Once toad-less, Australia now seethes with the warty invaders, which arrived in 1935. Still on the march, giant toads continue to spread across the warm north of Australia, heading into the Outback's vast, primeval marshlands. Millions of dollars have been spent to stem the tide since the toads began their rampage, and Australian scientists are scrambling to isolate a pathogen that could weaken or kill off the hungry toad horde, while not affecting their country's sensitive native frogs.



JESSIE COHEN/NZP

BUFO MARINUS.

Other recent amphibian invasions include tiny Puerto Rican coqui frogs (*Eleutherodactylus coqui*) now thriving in Hawaii—where their loud, beeping choruses disturb hotel-bound tourists—as well as treefrogs from mainland Ecuador that have popped up in settled areas of the Galapagos Islands. (Neither island chain has native amphibians.) The lake frog (*Rana ridibunda*) has been introduced to wetlands in Russia's Ural Mountains, where it displaces native species, while Cuban treefrogs (*Osteopilus septentrionalis*) brought to south Florida are eating the indigenous treefrogs there.

Meanwhile, an all-American favorite, the bullfrog (*Rana catesbeiana*), is bullying its way across the U.S. West (where it's not native), as well as Europe, parts of South America, Israel, Indonesia, Malaysia, and Singapore. With its large, luscious legs, the bullfrog has most often been introduced as a food crop. Like the giant toad and other invaders, it out-competes—or consumes—native amphibians and other small animals in its conquered territory.

"Bullfrogs will eat anything that moves that they can fit into their mouths—even each other," says Mike Lannoo, an associate professor at Indiana University School of Medicine, and member of DAPTF's Invasive Species Specialist Group. Generally speaking, says Lannoo of the bullish invaders, "where bullfrogs are, other amphibians aren't."

—Howard Youth

FOR MORE INFORMATION:

Minnesota New Country School Frog Project
www.mncs.k12.mn.us/html/projects/frog/frog.html

Frogweb
www.frogweb.gov

Declining Amphibian Populations Task Force (DAPTF)
www.open.ac.uk/OU/Academic/Biology/J_Baker/JBtxt.htm

Frogwatch
www.mp2-pwrc.usgs.gov/frogwatch

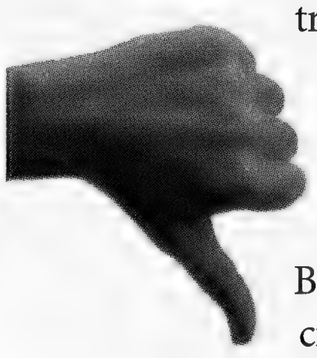
BIO-ALMANAC

GOOD NEWS

A new era of conservation began January 21 with the creation of an 8,400-acre preserve on the island of Dominica—officially, the first national park of the 21st century. Morne Diablotin National Park, named for the 4,747-foot volcano within its boundaries, contains a rare oceanic rainforest habitat harboring two endangered parrots found there and nowhere else: the sisserou, or imperial Amazon parrot (*Amazona imperialis*); and the jaco, or red-necked parrot (*Amazona arausiaca*). The jaco population has recently rebounded to nearly 500 individuals, but the total sisserou population may be fewer than 200.

A project 20 years in the making, the creation of Morne Diablotin was finalized with the help of the Loxahatchee, Florida-based Rare Species Conservatory Foundation (RSCF)—an organization that went $300,000 into debt to purchase land for the park. Formally protecting the island's pristine rainforest had suddenly become urgent. According to RSCF director Paul Reillo, the European subsidization of the banana industry on Dominica will end this year, making logging more attractive on the island—and conservation measures more critical. Measuring 29 miles long by 16 miles wide, the island of Dominica is more than half-covered by standing forest, and may be the only one of the Caribbean's Windward Islands that Columbus would recognize today, says Reillo. Morne Diablotin will join neighboring Morne Trois Pitons National Park on Dominica as the only two Natural World Heritage Sites in the Caribbean. For more information on RSCF or the new national park, log onto www.rarespecies.org.

BAD NEWS



Quieter, but just as troubling as the crash of massive hardwoods felled for timber on Borneo, is the crash of a whole ecosystem fueled by these hardwoods' seeds. According to a December 10, 1999, article in *Science* by Lisa Curran of the University of Michigan and her colleagues, no new dipterocarp hardwood seedlings have taken root for eight years at a study site in Gunung Palung National Park on Indonesian Borneo—bad news both for the trees, and for the animal species that depend upon them.

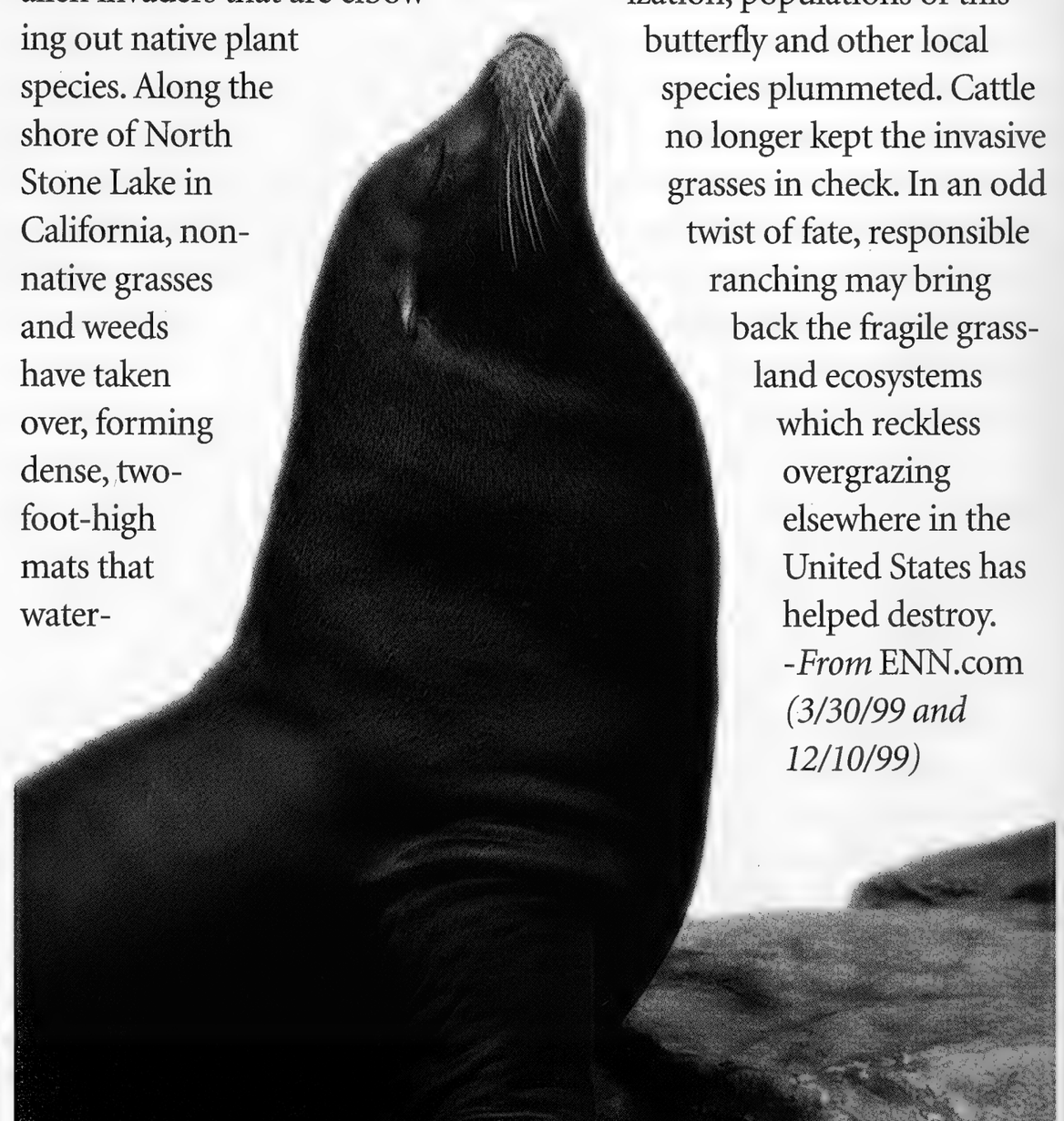
Dipterocarps, the major canopy tree family on Borneo, bear fruits in synchronized bursts normally triggered by El Niño. The fruiting bursts overwhelm frugivorous animals so enough seeds survive and take root. Logging and slash-and-burn farming outside Gunung Palung, however, have made the park a shrinking island for hardwood populations. Curran's team reported 175 pounds of seed per acre in 1991, but only 16.5 pounds per acre in 1998. Fruit-eaters like orang utans and parakeets appear to be munching all the dipterocarp seeds that are produced, leaving none to produce the next generation of trees. Unless more hardwood forests are protected on Borneo and elsewhere in Southeast Asia, the ecosystem that depends on dipterocarps—and the Indonesian logging industry which exports $6 billion worth of these hardwoods each year—may soon be yelling timber.

GRAZING OUT ALIENS

While the clearing of natural habitat for farmland has greatly damaged ecosystems across the planet, grazing may actually benefit the environment in certain circumstances. Researchers in California and Idaho have found that sheep and cattle often eat away invasive grasses and weeds—alien invaders that are elbowing out native plant species. Along the shore of North Stone Lake in California, nonnative grasses and weeds have taken over, forming dense, two-foot-high mats that waterfowl avoid. In a controlled experiment, refuge managers are permitting cattle grazing in order to observe its ability to reduce weeds without the use of pesticides, and to create shorter, new growth patches where waterfowl have better views of predators.

Grazing may be essential to the survival of the threatened Bay checkerspot butterfly (*Euphydryas editha bayensis*) in the San Francisco Bay area, according to an article by Stuart B. Weiss in the December 1999 issue of *Conservation Biology*. Car emissions in the Bay Area have created an excess of nitrogen oxides, essentially fertilizing exotic grass species that thrive on nitrogen at the expense of indigenous wildlife. The Bay checkerspot butterfly relies on a variety of native forbs and grasses during its larval stage. When ranching in south San Jose gave way to urbanization, populations of this butterfly and other local species plummeted. Cattle no longer kept the invasive grasses in check. In an odd twist of fate, responsible ranching may bring back the fragile grassland ecosystems which reckless overgrazing elsewhere in the United States has helped destroy.

-*From* ENN.com *(3/30/99 and 12/10/99)*



JESSIE COHEN/NZP

CALIFORNIA SEA LION (*ZALOPHUS CALIFORNIANUS*).

WHAT'S IN A NAME?

Hermes, the high-speed courier of Greek mythology who sported wings on his heels, may have been agile in the air. But when it comes to manuevering in the water, he has nothing on the wing-footed mammals: the seals, sea lions, and walruses of the suborder Pinnipedia.

The name "pinniped" derives from the Latin words *pinna* (feather or wing) and *pedis* (foot), describing sleek hind limbs that have evolved into flippers. The sea lions and furred seals belonging to the family Otaridae (from the Greek root *ot* for 'ear') have scroll-like external ear flaps, and propel themselves through the water with their fore-flippers. True seals in the family Phocidae (from the Greek root *phoc* for seal) lack ear flaps and are unable to raise themselves on their foreflippers, opting instead to flop ungracefully across ice and rock. Unlike eared seals, true seals swim by powerful side-ways movements of their hindquarters, using their foreflippers only for steering.

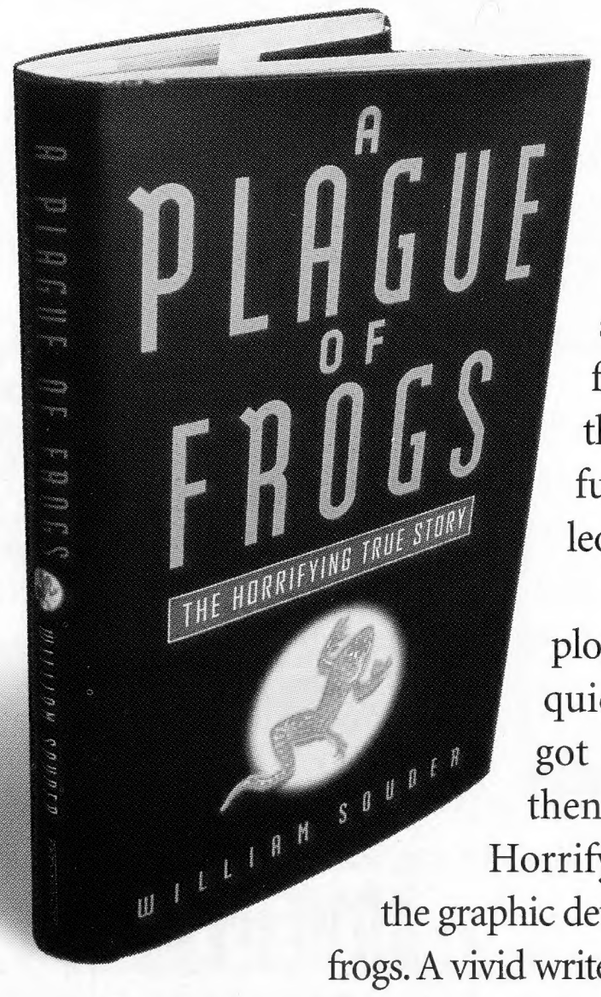
Eighteenth-century zoologists occasionally observed walruses using their tusks as ice axes to haul themselves out onto ice floes, and named the family of walruses Odobenidae, a contraction of the Greek words *odontos* and *baenos*, literally meaning "tooth-walk." Those fearsome looking tusks make good ice choppers, but are primarily used by males to establish their place in the dominance hierarchy. Simply by adopting postures that display the size of their tusks, dominant males can move unchallenged into the most comfortable or advantageous positions on the beach.

—Compiled by Alex Hawes and Tim Stoddard

BOOKS, NATURALLY

***A Plague of Frogs: The Horrifying True Story.* 2000. William Souder. Hyperion, New York, 304 pp. Hardcover, $23.95.**

The mutant frog mystery, briefly reprised in Howard Youth's article in this issue of *ZooGoer*, seemed like old news to me, having followed the story in a distant, general way since it broke in 1995. So I opened to the first page of *A Plague of Frogs* with a reluctant sense of duty rather than interest. And, to be sure, the book began with the now familiar tale of the Minnesota school kids who first stumbled on the infamous pool full of deformed leopard frogs.



Stifling yawns I ploughed ahead. But quickly the story got interesting, and then, yes, horrifying. Horrifying, first, just in the graphic details of the hapless frogs. A vivid writer, William Souder doesn't need photographs to make you see how hideous the deformed frogs could be. Frogs with no hind legs to frogs with five or nine legs of varying degrees of development, all merit his descriptive attention. But Souder is not being sensational. In fact, he clearly feels much sympathy for these creatures, many of which can barely move and may starve even before a snake or raccoon finds them easy pickings.

The story Souder tells is horrifying for its depiction of the deformed frogs, whose presence was soon documented at sites throughout the northern tier of the United States and into Canada. It is more fascinating for its tale of the investigation of the sudden appearance of all these mutants, and what this means for the environment and for the people, and other creatures, who share it.

Scarily, by book's end in the fall of last year, the mystery still had not been solved. Viruses, parasites, pesticides and other chemicals, excess UV light, leg-amputating predators, some combination of these, and even natural "mistakes" have all been implicated. Each has its champion or champions among the scientists studying the problem. And while most agree the outbreak of deformities means something, and something bad, no one is sure exactly what. Further, how and whether the deformity problem is linked to the wider decline of frogs, also likely due to multiple causes, is not at all clear.

A Minnesota science journalist whose reporting on the frog deformities has appeared in *The Washington Post*, among other publications, Souder began following this story early on. He got to know the cast of characters who play various roles in the drama, including the schoolteacher whose students caught the first deformed frogs, and a worried family whose rural Minnesota pond is now a scientific study site. For five years, their pristine-seeming pond has had one of the highest percentages of deformed frogs known. This is the same pond the kids used to swim in.

Souder closely followed the political infighting among the many characters, who variously represent local, state, or federal regulatory and research agencies, conservation organizations, academic departments, and, most especially, their own interests and ambitions, as careers and reputations are being made and lost in the fray. Souder himself seems to become a bit of a gadfly as he works to understand all angles of the problem. To be fair, however, in the book he seems not to take sides and interprets sophisticated science accurately and clearly.

Ultimately, *A Plague of Frogs* exposes the politics of environmental science, which is like the politics of science generally, only worse, perhaps because environmental issues themselves are so political. One can't help but feel at the end of this book that there might be better solutions to the deformed frog mystery, more quickly achieved, if all of the players were working toward the common good. That being a naïve hope, I'm sure glad the frogs in my backyard pond seem normal—so far.

—Susan Lumpkin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